I-70 EAST
ENVIRONMENTAL IMPACT STATEMENT

I-70 EAST

SUPPLEMENTAL DRAFT ENVIRONMENTAL IMPACT STATEMENT
AND SECTION 4(F) EVALUATION

HYDROLOGY AND HYDRAULICS TECHNICAL REPORT

ATTACHMENT M

AUGUST 2014

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List of acronyms

BFE	Base flood elevation
BMP	Best management practice
CDOT	Colorado Department of Transportation
CEQ	Council on Environmental Quality
cfs	Cubic feet per second
CLOMR	Conditional Letter of Map Revision
CUHP	Colorado Urban Hydrograph Program
Denver	City and County of Denver
DSDMP	Denver Storm Drainage Master Plan
EIS	Environmental impact statement
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Maps
FIS	Flood Insurance Study
FTA	Federal Transit Administration
GIS	Geographic Information System
LOMR	Letter of Map Revision
MS4	Municipal Separate Storm Sewer
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
PACT	Preferred Alternative Collaboration Team
RCB	Reinforced concrete box
RCP	Reinforced concrete pipe
RTD	Regional Transportation District
SFHA	Special flood hazard areas
UDFCD	Urban Drainage and Flood Control District
UFA	Urban flooding area
WMD	Denver Wastewater Management Division
WQCD	Water Quality Control Division

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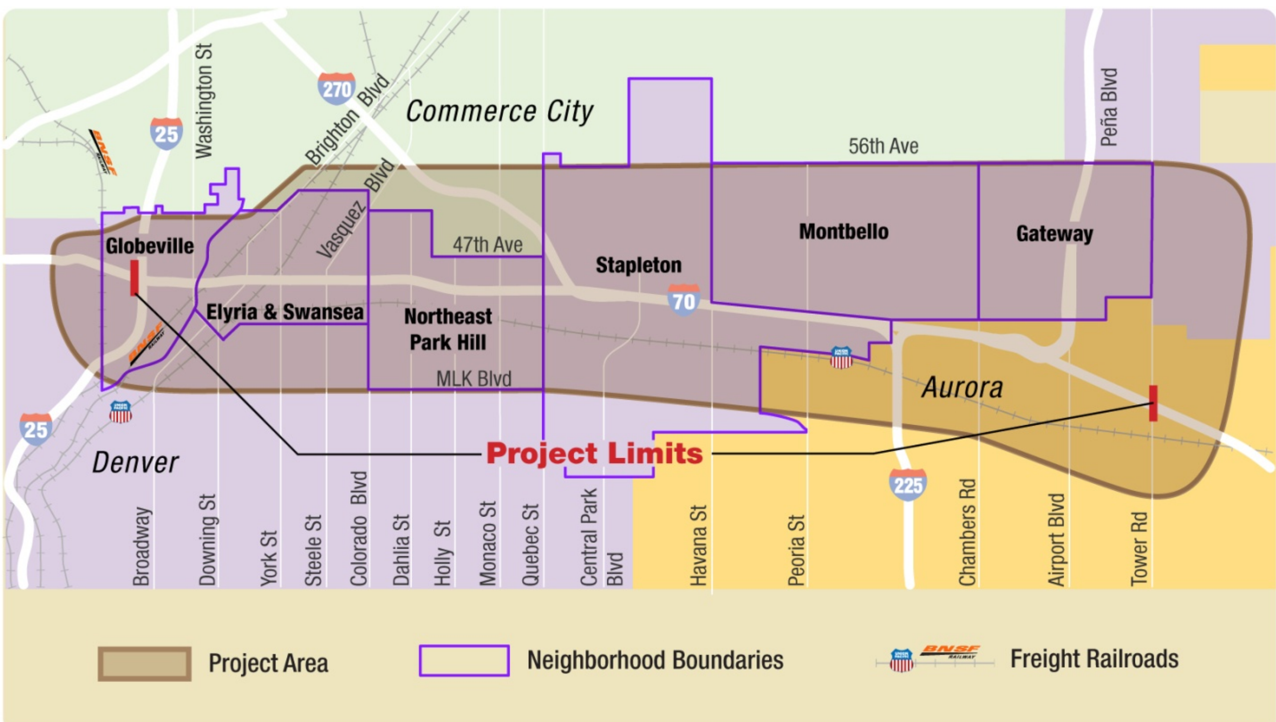
1. Introduction

The I-70 East Environmental Impact Statement (EIS) is a joint effort between the Federal Highway Administration (FHWA) and the Colorado Department of Transportation (CDOT). The intent of the EIS is to identify potential highway improvements along I-70 in the Denver metropolitan area between I-25 and Tower Road and to assess their potential effects on the human and natural environment.

1.1. Project limits

As shown on Figure 1, the project limits extend along I-70 between I-25 and Tower Road. The project area covers portions of Denver, Commerce City, Aurora, and Adams County. This area includes the neighborhoods of Globeville, Elyria and Swansea, Northeast Park Hill, Stapleton, Montbello, and Gateway. The portion of Aurora in the project area is referred to as the Aurora Neighborhood in this report. Each resource has a specific study area based on the resource.

Figure 1. Project area



1.2. Project background

Analysis of I-70 began in June 2003 as part of the I-70 East Corridor EIS, a joint effort conducted by CDOT, FHWA, the Regional Transportation District (RTD), the Federal Transit Administration (FTA), and the City and County of Denver (Denver). In June 2006, CDOT and RTD determined that the highway and transit elements of the I-70 East Corridor EIS process serve different travel markets, are located in different corridors, and have different funding sources. Therefore, the highway and transit components of the analysis were separated. After the project separation, the Draft EIS, published in November 2008, fully evaluated the alternatives that addressed the purpose and need of the project and, therefore, made it through the screening process. With the release of the 2008 Draft EIS, the public and agencies had an opportunity to review and comment on it. Public hearings were held to present the information and encourage formal comments. Due to the complexity of the project and the extensive amount of public comments received during the formal comment period, the project team decided to form the Preferred Alternative Collaborative Team (PACT) as part of a collaborative process with project stakeholders to recommend a preferred alternative. Through this collaborative process, additional analysis was performed, which resulted in the elimination of two previous alternatives and the addition of a new alternative option.

Because more than four years has passed since the 2008 Draft EIS was first published in 2008, many federal and state regulations and requirements have changed. Additional analysis and public involvement efforts were performed to determine the validity of the alternatives that were considered reasonable alternatives in the 2008 Draft EIS. Based on the public comments, the additional analysis, and the PACT collaborative process, the project team determined that the Realignment Alternatives are no longer reasonable. Consequently, a new alternative option was designed to address the public concerns and incorporate their comments. Due to the changes in the alternatives, outdated census data, and new federal and state laws and regulations, the analysis in the 2008 Draft EIS was revisited and a Supplemental Draft EIS was written.

2. Report overview

This report provides hydrologic and hydraulic analysis of offsite and onsite drainage basins and defines project area flooding and existing Federal Emergency Management Agency (FEMA) floodplains on and around the project area for existing conditions and the different highway alternatives. The hydrologic analysis and the corresponding flow rates crossing the I-70 East project area are derived from existing drainage studies that cover the I-70 East project area. A preliminary onsite hydrological analysis was done to estimate flows and size storm sewers to route the onsite flows to the South Platte River. Several pipe alignments for routing onsite flows were examined, and the most practical alignment is proposed. Offsite flows interacting with the proposed alternatives were analyzed, and a description of offsite flows and their management is presented. This assessment also includes preliminary recommendations for improvements to existing cross-culverts and bridges that drain areas upstream from the project area. Additional design and analysis for the proposed drainage facilities including pipe and pond sizes will be conducted as part of final design .. The proposed drainage facilities have been designed and analyzed for the 100-year storm event.

3. Resource definition

The project alternatives are located in the northeastern part of Denver and cross portions of Commerce City, Aurora, and Adams County. The project area climate is semi-arid continental. The area is a transition zone, from foothills to a plains climate. The area has cold, dry winters and warm, relatively dry summers.

The drainage recommendations presented in this document are based on the best information available. This is a draft document and should not be used as the sole basis for final design, construction, remedial action, or as the basis for major capital decisions.

4. Applicable laws, regulations, and guidance

This section discusses applicable laws, regulations, and guidance as they pertain to the analysis of hydrology and hydraulics in the EIS.

4.1. Laws and regulations

The following laws and regulations will be followed to address potential drainage issues in the EIS.

4.1.1. National Environmental Policy Act

The National Environmental Policy Act (NEPA) of 1969, as amended, (42 United States Code §4321 et seq., Public Law 91-190, 83 Stat. 852), mandates that transportation decisions involving federal funds and approvals consider social, economic, and environmental factors in the decision-making process. NEPA also requires that agencies making such decisions consult with other agencies and involve the public, disclose information, investigate the environmental effects of a reasonable range of alternatives, and prepare a detailed statement of the environmental effects of the alternatives.

4.1.2. Council on Environmental Quality Regulations

The Council on Environmental Quality (CEQ) Regulations Part 1502, Environmental Impact Statement, (40 Code of Federal Regulations §1502.14), requires that an EIS be prepared when a proposed action is projected to have a significant impact on the quality of the human environment. Under the Council on Environmental Quality Regulations, an EIS must provide full and fair discussion of significant environmental impacts and inform decision makers and the public about project alternatives.

4.1.3. Executive Order 11988

Executive Order 11988 requires that federal agencies avoid, to the extent possible, long- and short-term adverse impacts associated with the occupancy and modification of floodplains and avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "… each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities" for the following actions:

- Acquiring, managing, and disposing of federal lands and facilities
- Providing federally undertaken, financed, or assisted construction and improvements
- Conducting federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulation, and licensing activities

4.1.4. National Flood Insurance Program

The National Flood Insurance Program (NFIP) was created by Congress in 1968 through the National Flood Insurance Act of 1968 (Public Law 90-448). It enables property owners in participating communities to purchase insurance protection against losses from flooding. Participation in the NFIP is based on an agreement between local communities and the federal government that states that if a community will adopt and enforce a floodplain management ordinance to reduce future flood risks to new construction in Special Flood Hazard Areas (SFHA), the federal government will make flood insurance available within the community as a financial protection against flood losses. The SFHAs and other risk premium zones applicable to each participating community are depicted on Flood Insurance Rate Maps (FIRM). The Mitigation Division of FEMA manages the NFIP and oversees the floodplain management and mapping components of the program. The program was first amended by the Flood Disaster Protection Act of 1973, which made the purchase of flood insurance mandatory for the protection of property within SFHAs.

4.1.5. Federal Highway Administration Technical Advisory T6640.8a

This FHWA advisory document provides guidance that the analysis of land use impacts should identify current development trends and state and/or local government plans and policies on land use and growth in the area that will be impacted by the proposed project.

4.2. Applicable guidance

All drainage design work associated with the I-70 East project would be performed in compliance with the following technical guidance:

- CDOT *Drainage Design Manual* (2004)

- CDOT Municipal Separate Storm Sewer Permit (2008)
- FHWA *Roadside Design Guidelines* (2003), based upon the American Association of State and Highway Transportation Official's *Roadside Design Guide* (2002)
- Denver *Storm Drainage Design and Technical Criteria Manual* (Denver Wastewater Management Division [WMD], 2006)
- Urban Drainage and Flood Control District (UDFCD) *Urban Storm Drainage Criteria Manual* (2001, Revised 2006)
- *City of Aurora Storm Drainage & Technical Criteria* (2005)
- *City of Commerce City Drainage Criteria Manual* (n.d.)
- *Adams County Storm Drainage Design and Stormwater Quality Regulations* (2001)
- *Arapahoe County Draft Stormwater Management Manual* (2012)
- Union Pacific Railroad *Hydraulic Design Criteria* (2003)

In addition, stormwater requirements for the following agencies would be incorporated, as necessary:

- Denver Water Board
- Colorado Water Conservation Board
- Colorado Department of Public Health and Environment

In locations subject to the design criteria of two or more entities, the most stringent criteria would be applied to the project design, unless otherwise noted.

4.3. Permits and approvals

Various permits may be necessary for construction and operation of this project. The listing herein is not all-inclusive. All permits required to perform the work would be determined during the design phase of the project.

4.3.1. National Pollution Discharge Elimination System Stormwater Discharge Permit

A National Pollution Discharge Elimination System (NPDES) Stormwater Discharge Permit from the Colorado Department of Public Health and Environment and the governing local jurisdictional entities (Denver, Aurora, Adams County) would be obtained prior to construction of the project, as per Section 402 of the Clean Water Act. Construction documents would include a stormwater management plan detailing the best management practices (BMP) to control erosion and sedimentation and the discharge of any pollutants that may enter stormwater and be transported to receiving waters.

Any new stormwater systems associated with this project would meet or exceed goals for discharge of runoff constituents (where these goals have been established) through the use of non-structural and structural BMPs.

4.3.2. Groundwater discharge permit

Any dewatering of groundwater during construction would be in accordance with the Water Quality Control Division (WQCD), Colorado Discharge Permit System Application for Construction Wastewater Discharge, to be obtained from the Colorado Department of Public Health and Environment.

Any permanent groundwater diversion would be permitted, in accordance with the WQCD's Colorado Discharge Permit System Application. WQCD has standards that govern discharge into receiving waters. All information needed to assist WQCD in their evaluation and establishment of a water quality standard for this permit would be provided, as required.

4.3.3. Section 404 permit

A Section 404 permit may be needed, as there is a possibility that construction activities could discharge dredged and fill materials into jurisdictional wetlands or waters of the U.S. The location of wetlands within the project area has been delineated in accordance with the approved procedures of the U.S. Army Corps of Engineers. Stipulations of this permit would be incorporated into project construction documents. A Section 401 water quality certification also may be required from the state to obtain the Section 404 permit.

4.3.4. Floodplain use permit

The location of floodplain areas would be delineated from the most current FIRM published by FEMA. A permit would be obtained from the Floodplain Administrator of the affected jurisdiction for any construction within areas delineated as Zone A, AE, AH, AO, or A99 on FIRM. A Conditional Letter of Map Revision/Letter of Map Revision (CLOMR/LOMR) process may need to be undertaken with FEMA if the proposed construction raises the regulatory base flood elevation of any floodplain.

4.3.5. Sewer use and drainage permits

Sewer use and drainage permits would be obtained for all connections. This includes temporary connections into any sanitary sewer or storm sewer systems that are owned by Denver WMD or that discharge into a storm or sanitary sewer system owned by Denver WMD outside of the CDOT right of way. Sewer use and drainage permits would be obtained for:

- Cutoffs of services lines
- Abandonment of sewers (sanitary or storm)
- Minor modification (manholes and inlets only)
- New or relocated service connections

Sewer use and drainage permits would be obtained from other affected local jurisdictions, as required.

4.3.6. Municipal separate storm sewer permit

Implementation of Municipal Separate Storm Sewer (MS4) Program elements within the project area would be undertaken, as necessary. These include, but are not be limited to:

- Illicit discharges into the storm sewer system
- Maintenance of structural controls

5. Existing conditions

This section discusses the existing conditions of the drainage system in the project area and includes a description of FEMA floodplains, background information on drainageways in and near the project, a flooding history for the area, major drainageways crossing the corridor, existing drainage structures, and completed drainage studies and projects in the area.

5.1. Drainage system background

The project area crosses the South Platte River and Sand Creek, which is a tributary to the South Platte River. The South Platte River, Sand Creek, and areas within the city where non-regulated flooding occurs need to be combined to understand the full background of the drainage area for the project. The history of the drainageways, including historical use and flooding events, along with engineering drainage studies and construction projects completed in the area were combined to develop the necessary background information.

Historically, the South Platte River played a key role in the development of the Denver metropolitan area. It served a number of purposes, ranging from the transportation of water from upstream basins and mountain reservoirs to the transportation of supplies and immigrants to the west. The South Platte River has served as the source of municipal, industrial, and agricultural water supply, as well as a way to dilute and discharge sewage effluent. Sand and gravel carried downstream to the Denver area became a source of income for Denver as it was used as the raw building materials for the infrastructure both in and around the city.

Sand Creek is the major tributary crossing in the project area. Sand Creek flows from the east and joins with the South Platte River north of the project area. Sand Creek experiences significant erosion and has a high erosion potential due to the creek bed being composed primarily of sandy alluvial soils.

5.2. Flooding events

Flood events in the project area include two separate types: (1) flooding of regulated floodplains, and (2) flooding of urban flooding areas (UFAs), which are potential areas of flooding with flood depths of 1.5 feet, not identified as SFHAs by FEMA. Both the South Platte River and the major drainageways that cross the project area have a history of flood events. These events have been documented in the *Denver Storm Drainage Master Plan* (DSDMP) (Denver WMD, 2009, revised 2010) and the more significant ones are highlighted in Section 5.2.3. of this report, Major Flood Events.

5.2.1. Regulated floodplains and major drainageways

Flooding of regulated floodplains and major drainageways in the corridor occurs at areas where the 100-year flows in the drainageways are channeled through structures (bridges and culverts). This produces a backwater effect that can cause the water surface upstream of the structures to rise, spread out, and produce flooding in the vicinity of the crossing. In some cases, the existing structures do not have the capacity for the 100-year flows, and the water overtops the structures, substantially increasing the flooding limits at the structure and for areas downstream.

The flows and hydraulics of the existing structures have been analyzed by FEMA and UDFCD in various flood insurance studies (FIS), flood hazard area delineations, and outfall system planning studies. The resulting flooding limits have been designated as regulatory “Floodplains and Floodways,” and are shown on the current FIRMs published by FEMA. The floodplains and floodways in the project area, identified as SFHAs, are shown in Figure 2.

Improvements to the drainageways and structures within the SFHA are subject to FEMA policy and regulations. The SFHAs require rigorous hydraulic modeling to accurately determine the effects of the new construction on the existing regulatory base flood elevation (BFE) and the floodplain and/or floodway. Generally, these regulations allow for increases in the BFEs of 0 to 1 foot depending on the type of flood zone. In cases where the BFE is increased, a CLOMR—followed by a LOMR—may have to be obtained from FEMA.

The CLOMR/LOMR process is a regulatory procedure that allows FEMA to review and examine the hydraulic models and proposed improvements. FEMA then determines if the floodplain changes are acceptable (e.g., increased flooding does not result in increased property damage or result in structures being placed in the regulated floodplain). If there is no increase in the BFE, then the analysis should be submitted to the governing agencies to verify that the CLOMR/LOMR process is not necessary.

5.2.2. Urban flooding areas

UFAs are the areas where DSDMP has determined that overland flooding occurs because the existing storm drain systems have insufficient capacity to convey the runoff from the various rainfall events. The DSDMP also labels these areas as potential ponding areas. There are several UFAs in the project area. In the majority of cases, it has been determined that the existing drainage systems are inadequate for rainfall events in excess of the 2-year storm. The DSDMP provides preliminary recommendations for stormwater infrastructure improvements to adequately convey the 2-year event in residential areas and the 5-year event in commercial and industrial areas. These proposed improvements may be constructed in the future as funding allows. Because the proposed improvements in the DSDMP would only provide conveyance for the 2-year and 5-year storm events, and the design criteria applicable to the corridor is based on the 100-year storm events, alternatives to route the onsite and offsite 100-year flows were studied specially for the Partial Cover Lowered Alternative. The alternatives presented in this document provide opportunities to address the UFAs along the 46th Avenue corridor. The construction of these facilities would provide some relief by reducing the amount of water traveling overland during major storm events in areas downstream (north) of the 46th Avenue corridor.

5.2.3. Major flood events

Flooding in Denver typically is due to short-duration, high-intensity precipitation events that occur between May and September. Denver has a documented history of significant flood events for the period of May 1844 to September 2013. Flooding in Aurora and Adams County is similar to that in Denver. These events show the seriousness of floods in this area and the need for proper design and anticipation of probable large storm events. The following major flood events occurred in the project area:

- On September 9 to 16, 2013, a complex weather pattern produced torrential rain along the Front Range of Colorado, unleashing deadly flash floods in and near the foothills, which lead to a major river flood event for the South Platte River valley. This flood was the most costly to date in Denver.
- On July 19, 1997, a severe thunderstorm in northeast Denver and northwest Aurora yielded 3.83 inches of rain in less than an hour, surpassing the old 1-hour record by more than 1.5 inches.
- On May 5 and 6, 1973, the South Platte Basin experienced a storm event that brought as much as 6 inches of rain to the area. This caused major flooding during the next two weeks along Clear Creek, Sand Creek, and the South Platte River. The damages from this flood event were estimated at around $120 million.
- On July 23 and 24, 1965, heavy rain fell over Denver and Aurora, washing out earthen bridges over Sand Creek and causing flooding of roads, streets, and bridges.
- On May 8 and 9, 1957, more than 4 inches of rainfall fell in a storm over eastern Colorado around Sand Creek. The floodwaters from this storm receded along Sand Creek within 12 hours, but still produced a discharge of approximately 25,000 cubic feet per second (cfs) at Stapleton International Airport. Most of the damages from this event were due to erosion undercutting houses, damaging bridges, and eroding railway embankments.
- In May 1948, a storm produced 8 inches of rainfall at the center of the storm in 4 hours. Discharge at the mouth of Sand Creek was estimated to be 15,000 cfs. Roads and culverts in the storm area were eroded and damaged. Much of the damage along Sand Creek was a result of erosion; there was also damage due to water inundation of homes and businesses.

Within the project area, there are several locations where significant flooding problems have occurred. One example of a significant flooding problem is the I-70/Colorado Boulevard interchange, where ponding depths at the existing drainage structures significantly exceed allowable criteria. Another area where significant flooding occurs is on the elevated portion of I-70 above York Street.

5.3. Major drainageways

There are two major drainageways within the project area: the South Platte River and Sand Creek. These drainageways are considered SFHAs and are regulated by FEMA. The FEMA flood zone information is listed in Table 1.

Table 1. Major drainageways

Stream or Drainageway	FEMA Flood Zone
South Platte River	Zone AE
Sand Creek	Zone AE

As alternative designs are developed, the hydraulics at each of these crossings will be analyzed to ensure that hydraulic capacity is adequate for the various flood events and that no negative effects to the regulatory floodplains result.

5.4. Existing drainage structures

Storm sewer systems or cross drainage structures currently exist within the project area. Major crossings for the drainage system under existing I-70 are discussed in this section.

Along the existing I-70 alignment, there are numerous existing drainage systems. Along the elevated portion, inlets are tied to storm drains that lie under the streets below I-70. Just west of Colorado Boulevard, I-70 returns to an at-grade highway. There is a system of inlets and storm sewers, from 15-inch diameter up to 30-inch diameter, that connect to a 42-inch storm sewer that heads north, just east of Colorado Boulevard and eventually connects to a 78-inch storm sewer that continues to head north and west and drains into the South Platte River by the York Street outfall.

East of Colorado Boulevard, a storm sewer system collects runoff from east of Dahlia Street and west of Monaco Street. These systems converge to a 72-inch reinforced concrete pipe (RCP) located under Dahlia Street that carries the drainage to the north toward Sand Creek. Along this portion of I-70, from Colorado Boulevard to just west of Quebec Street, there are sanitary sewer and water lines that border I-70 on both sides.

East of Monaco Street there is a storm sewer system that carries runoff from I-70 to Sand Creek. A 48-inch pipe crosses just west of Sand Creek that carries the outfall from this system.

According to Denver's Geographic Information System (GIS) data, there are no other major crossings heading east on I-70 to the east project limit. Before design, a walkthrough of the I-70 East project area should be conducted to confirm that no other major crossings have been constructed.

5.5. Related studies and projects

The DSDMP provides updated stormwater hydrology, hydraulics, and capital improvement planning for the stormwater drainage basins in Denver. Additional studies for the Lower Montclair FLO-2D Analysis and the Park Hill Outfall System Plan provide more detailed information regarding the hydrology and hydraulics of the I-70 project corridor. The project team extensively reviewed these documents and coordinated their use with Denver staff. The overall master plan basin map is included in Appendix B. FLO-2D exhibits from the Lower Montclair and Park Hill studies also are included.

5.6. Other related issues

This section describes issues related to hydrology and hydraulics to further outline the existing drainage conditions within the project area. It discusses additional aspects that may be required as the project develops and also summarizes the findings of other memoranda produced for the Draft EIS and Supplemental Draft EIS.

5.6.1. Wetlands and waters of the U.S.

Water bodies that may be considered jurisdictional waters by the U.S. Army Corps of Engineers include streams/channel beds, wetlands, and ponds (including perennial and seasonal ponds). Wetlands are areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. All wetlands effects and effects to waters of the U.S. are identified within the project limits in the *I-70 East Wetlands and Waters of the U.S. Technical Report* (2013).

5.6.2. Future land use

Future land use changes for Denver's drainage basins have been identified in *Blueprint Denver* (Denver, 2002), which identifies the major transportation network improvements and established the basis for future land use planning. The DSDMP has incorporated these data, and as such, the hydrology presented herein is consistent with *Blueprint Denver*.

5.6.3. Water quality, retention, and erosion control requirements

As project alternatives develop, water quality facilities should be incorporated to the extent practicable within the project limits. These facilities should be designed to all appropriate local, state, and federal requirements to meet current NPDES requirements, and will be documented in the Final EIS. This process will be refined as the project continues and suitable locations for water quality BMPs are identified. All water quality measures and proposed BMPs will be developed in close coordination with the environmental scientists working on the project.

5.6.4. Outfall protection

Outfall protection will be required at culvert outlets and should be designed as the final design of the project is completed. The majority of outfall protection should be designed in accordance with standard CDOT or UDFCD requirements. Areas requiring significant outlet protection should be designed individually.

6. Hydrologic analysis

Flows at critical locations within the project area have been obtained from the sources mentioned previously. Generally, flows crossing the alternatives have been obtained from the DSDMP, and flows in the major channels have been obtained from the FEMA FIS or urban drainage hydrology and hydraulic studies. For the Partial Cover Lowered Option, a preliminary hydrologic analysis was done for the onsite drainage area lying between the high points of the lowered section.

The study area for the floodplains and drainage is the construction limit of the project alternatives. It includes bridge crossings at the South Platte River and Sand Creek, as seen in Figure 2. Both streams include a delineated 100-year floodplain.

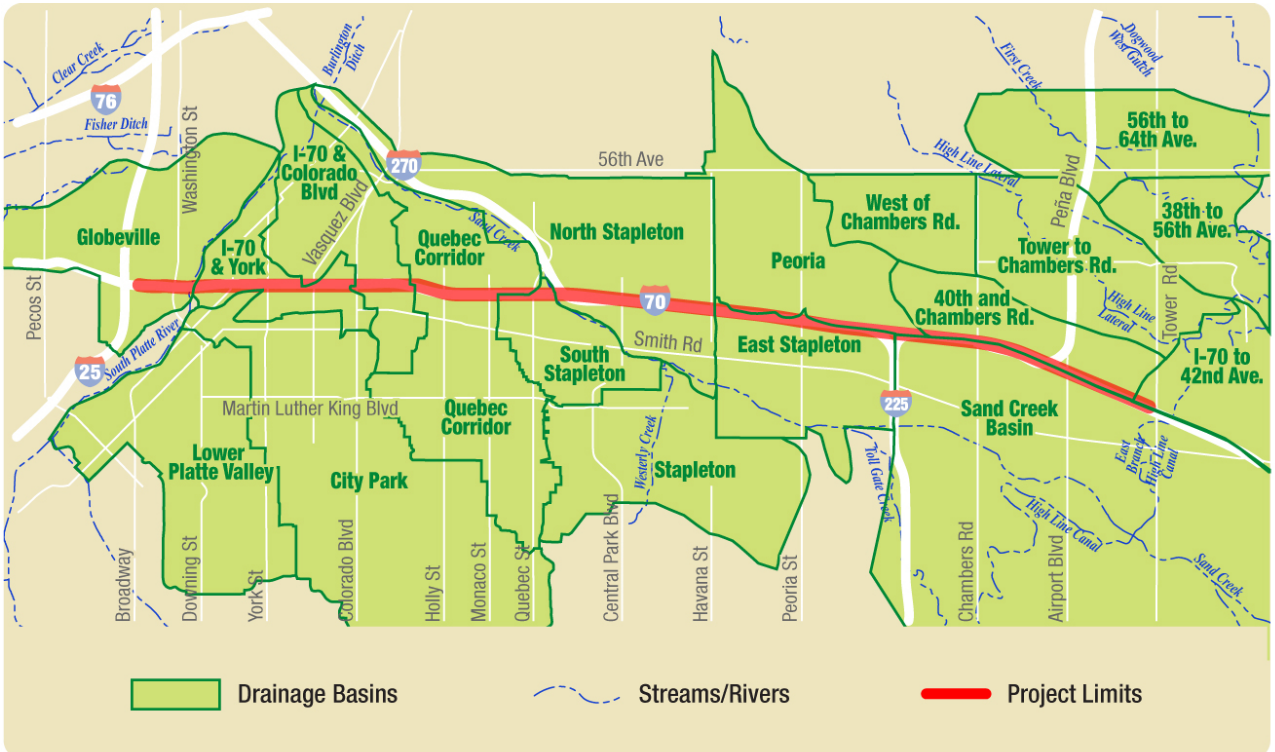
Figure 2. Floodplains and drainage study area

6.1. Basin descriptions

Drainage basins have not been delineated for this study; however, the basin boundaries from the previous DSDMP are shown in Figure 3. Basins draining through the project area generally are developed, being composed of both residential and commercial growth. From I-25 to Tower Road, I-70 is bounded by completely developed land both north and south of the highway. This is significant to the project because developed land results in increased stormwater runoff. Typically, undeveloped land in the Denver metropolitan area can be expected to generate up to 1 cfs of stormwater runoff per acre of drainage basin for a 100-year flood event. Developed land, such as that along the I-70 corridor, can generate stormwater runoff from 2 to 5 cfs for a 100-year event. This increase in runoff can and does create flooding problems when not mitigated by stormwater detention facilities. A proportional increase occurs for all runoff events.

Many larger basins that have been studied previously contribute runoff to the major drainageways in the project area. The largest of these drainage basins is the South Platte River drainage basin. This basin is composed of approximately 4,000 square miles of land. Although the South Platte River has the largest drainage basin, the largest discharge is seen in Sand Creek, the next largest drainage basin, which covers an area of approximately 189 square miles. This is mainly due to the presence of the Chatfield Reservoir, south of Denver, which serves as a flood retarding structure, as well as a recreational and water supply facility.

Figure 3. Major drainageways



6.2. Rainfall data

As mentioned previously, flooding in Denver is typically due to short-duration, high-intensity precipitation events between the months of May and September. These rainfall events have been well documented by the National Oceanic and Atmospheric Administration (NOAA), as well as the UDFCD. Studies performed by these agencies have resulted in the development of design rainfall events for the Denver metropolitan area. For purposes of this analysis and many of the hydrologic studies previously performed along the corridor, a 1-hour rainfall event has been used. This number represents the estimated maximum rainfall that will occur over a 1-hour period for a family of rainfall events from the 2-year to the 100-year event. These events also can be described in terms of their probability of occurring in any given year. For instance, a 2-year event has a 50-percent chance of occurring in any given year and a 100-year event has a one-percent chance of occurring in any one year. These data are presented in the *Denver Storm Drainage Design and Technical Criteria Manual* (Denver WMD, 2006). Derivation of rainfall data is similar for Commerce City, Adams County, and Aurora and their data are contained in the respective drainage criteria manuals for each of these municipalities.

7. Major drainage features along alignments

There are various locations within the project area where existing drainage conditions might be expected to influence the selection of the highway alternatives. This section provides descriptions of the existing drainage conditions at those design locations, discusses the types of flooding problems encountered, the magnitudes of flows, and foreseeable solutions. Figure 4 shows the design locations noted in the following sections. Drainage issues are discussed by the following areas:

- I-25 to Brighton Boulevard
- Brighton Boulevard to Dahlia Street
- Dahlia Street to I-270/I-70 interchange
- I-270/I-70 interchange to I-225
- I-225 to Tower Road

As noted earlier, significant flooding and drainage problems have been documented within the project area; the most recent flood event having occurred in September of 2013. The design locations between I-25 and I-270 are identified as 1-H through 8-H, and shown on Figure 4. These locations were selected based on the results of prior studies. The design locations represent the area where stormwater runoff is routed across the I-70 East project alignments, based on topographic features, low points in the ground, and man-made conveyances.

Figure 4. Drainage design locations

7.1. I-25 to Brighton Boulevard

Improvements on this section of I-70 are proposed to consist solely of restriping for additional lanes. Existing drainage conditions are documented in the DSDMP. This section of I-70 is located in Denver basin 0059-01, (Globeville-Utah Junction). At present, stormwater runoff is carried through a system of storm drains that ultimately discharge into the South Platte River. No significant changes to existing drainage conditions are anticipated.

7.1.1. Design location 1-H

The hydrologic modeling for the Globeville basin (0059-01) has demonstrated that the elevated portion of I-70 immediately west of the South Platte River is located above a UFA. This area is also mapped as a

FEMA floodplain in the current FIRM. The area below the viaduct is subject to flooding; however, because no reconstruction work is proposed here, no improvements will be proposed.

7.1.2. Design location 2-H

Existing eastbound and westbound bridge structures over the South Platte River—for both the main line and associated on and off ramps—are included at this design location. Construction of the current bridge structures was completed in 2004. These structures were designed to provide conveyance for the 100-year flood event. All flows in the channel are contained entirely within the structure openings. These structures are identified as CDOT structure IDs E-17-UW, E-17-UX, E-17-UP, and E-17-UQ. An updated storm drain also was constructed below the new structures in 2004, and no changes to this system are anticipated.

7.2. Brighton Boulevard to Dahlia Street

Under existing conditions, I-70 is primarily located on a viaduct. Although this is an elevated portion of the highway, significant flooding problems have been experienced both on the viaduct and in the surface streets below. Flooding on the highway at these locations is due to undersized existing inlets that do not adequately drain the viaduct. Ponding occurs on the viaduct between the concrete barriers on the outside edges of the travel way because of runoff that is not captured by the existing inlets. Existing drainage conditions are documented in the DSDMP. This portion of I-70 is located in DSDMP drainage basin 0060-02 (I-70 and York Street). The drainage basin consists of a mix of industrial and residential land uses and is fully built out. The offsite drainage along the south side of I-70 follows more or less in a southeast-northwest direction toward the South Platte River. There are several drainage crossings that are capable of handing flows that are less than a 1-year event. During storm events, surface flooding inundates the project area.

7.2.1. Design location 3-H

Hydrologic analysis of this area was provided in the Lower Montclair Basin study and shows surface runoff in this area may exceed 4,000 cfs for a 100-year peak runoff event. This surface runoff flows under the existing viaduct from south to north and ultimately drains to the South Platter River.

7.2.2. Design location 4-H

At design point 4-H, I-70 crosses over York Street and there is a low point in the profile of the existing viaduct. Severe flooding has been experienced both on the highway and on York Street at this location. An existing 72-inch storm drain crosses under I-70 below York Street to provide drainage for the area south and east of the viaduct. The estimated 100-year flow at this location is 713 cfs. The capacity of this storm drain is significantly less than the peak flow rate, and York Street serves as the primary conveyance element for the runoff from major storm events. As mentioned previously, the existing inlets that drain the low point of the I-70 viaduct are inadequate and, as a result, flooding occurs on this portion of I-70.

7.2.3. Design location 5-H

Design point 5-H is the area near the I-70/Vasquez Boulevard interchange. This section of the highway lies in the I-70 and York Street (0060-02) drainage basin of the DSDMP. A very large drainage area (Denver basins 4400-02 and 0060-01) to the south and east of this location drains toward I-70. The existing storm drain system is not adequately sized to convey storm drainage events in excess of the 2- to 5-year peak runoff event. At design location 5-H, flows in excess of the capacities of the existing storm drains in the I-70 and Colorado Boulevard basin and the I-70 and York Street basin combine and flow below the I-70 viaduct in a northerly direction. The total estimated flow at this location during the 100-year event is 400 cfs. The basin is currently fully developed and changes in future land use or redevelopment can be expected to have minimal effect on the peak flow rates.

7.2.4. Design location 6-H

Design location 6-H is located at the I-70/Colorado Boulevard interchange. This portion of the highway is at grade and lies within the I-70 and Colorado Boulevard drainage basin of the DSDMP (0060-01). It is also the low point of a sag vertical curve in the highway profile. During the 100-year storm event, approximately 500 cfs crosses the highway in a northerly direction.

7.2.5. Design location 7A-H

At design location 7A-H (Dahlia and I-70), approximately 168 cfs flows overland along Dahlia Street under I-70 during the 100-year storm event. In addition to these specific locations, I-70 is an embankment that impounds runoff on the south side of the highway from Colorado Boulevard to Holly Street prior to flowing over the highway.

7.3. Dahlia Street to I-270

The portion of I-70 from Dahlia Street to I-270 generally will be reconstructed at grade and will cross over Sand Creek on the structure just east of the I-70/Quebec Street interchange. Existing drainage conditions are documented in the DSDMP. This section of I-70 is located in the DSDMP Sand Creek drainage basin, north Stapleton, Quebec Street corridor, and south Stapleton (0060-01, 4400-01, 4400-02, and 4400-03).

7.3.1. Design location 8-H

At this design location, I-70 would cross over Sand Creek. There are separate bridge structures over this channel for the eastbound and westbound lanes. Construction of the current bridge structures was completed recently. These are identified as CDOT structure IDs E-17-GE and E-17-BY. Based on the current FEMA FIS for Sand Creek, the entire 100-year estimated flow is contained within the hydraulic opening of the current structure and no overtopping of I-70 occurs. Sand Creek in this location is identified as a Zone AE SFHA. Zone AE floodplains have been studied in significant detail and have BFEs. In general, local floodplain ordinances limit rises in water surface to less than 1 foot due to construction or improvements. Sand Creek maintains the same flow rate throughout the project area; therefore, the same design will apply at all Sand Creek crossings.

7.4. I-270 to I-225

The portion of I-70 from I-270 to I-225 generally will be reconstructed and widened at grade along the current alignment. Existing drainage conditions will be maintained, and areas currently subject to flooding during rainfall events would remain subject to flooding. Those sections of the highway that will be widened and reconstructed at existing grades or profile grades similar to existing may require investigation as part of the Final EIS for improved cross drainage structures, new roadside ditches, and new trunk storm drains and detention systems to reduce flows across the highway to meet design criteria.

The hydraulic openings of new bridges will be designed to meet FEMA requirements. New bridges located over FEMA-regulated floodplains will be designed to meet the regulations regarding their affect on the existing regulatory BFEs and floodplain limits.

7.5. I-225 to Tower Road

The final section of I-70 analyzed begins at I-225 and proceeds east to Tower Road, the east terminus of the project. This portion of I-70 generally will be reconstructed and widened at grade along the existing alignment. Existing drainage conditions may be maintained, and areas currently subject to flooding during rainfall events may continue to remain subject to flooding. Those sections of the highway that will be widened and reconstructed at existing grades or profile grades similar to existing, may require investigation of improved cross drainage structures, new roadside ditches, and new trunk storm drains and detention systems to reduce flows across the highway to meet design criteria.

The hydraulic openings of new bridges will be designed to meet FEMA requirements. New bridges located over FEMA-regulated floodplains will be designed to meet the regulations regarding their affect on the existing regulatory BFEs and floodplain limits.

7.6. Summary of major drainage features

Table 2 summarizes the existing major crossings (larger than 48 inches) for the project. Peak flows for the 100-year event are shown for drainageway crossings only. Where storm sewer systems cross the proposed project, peak flows are not shown. These flows occur as both pipe flows and overland flows. Through further analysis, 100-year peak flows must be determined when a preferred alternative has been identified.

Table 2. Summary of highway cross-drainage structures

Crossing Name/Stream	100-Year Peak Flows (cfs)	Existing Structure	Cross Street Intersection	Notes	Design Location*
South Platte River	22,300	bridge			2-H
Storm sewer system	713	72" RCP	York Street	Surface overflow	4-H
Storm sewer system	224	48" RCP	Dahlia Street	Surface overflow	7-H
Storm sewer system	293	48" RCP	Quebec Street	Surface overflow	N/A
Sand Creek	30,000	bridge			8-H

**See Figure 4 for design locations*

8. Design criteria

This section introduces design criteria compiled for this project. These design criteria identify the design frequencies and allowable maximums and minimums to be used in the design of new drainage elements, including storm drains, inlets, culverts, bridges, and detention facilities. These criteria also were used in evaluating the adequacy of existing drainage elements and systems.

The drainage criteria are summarized in the *I-70 East Corridor Drainage Criteria Technical Memorandum* (see Appendix A). While these criteria have been based on the most recent published guidelines, it is possible these may be updated during the course of this project as changes are made.

Because of the functional classification of the highway and its locality, the design criteria have been based on the design standards published by CDOT, UDFCD, Denver, Adams County, and Aurora. Culverts under the I-70 highway are designed to carry the 100-year frequency peak flows. Storm drain systems constructed along highways, where required, are designed to limit the spread of water onto the travel way during the major storms. Storm drains in other streets and parking facilities usually are designed for minor storms only, typically the 2-year, 5-year, or 10-year events.

Bridges will be designed to convey the 100-year frequency flows with required freeboard.

Facilities will ultimately be designed to meet the drainage criteria developed for the corridor. For the purposes of this report, the criteria are applied to identify significant effects given existing drainage conditions for potential highway alternatives. The drainage design criteria provide a basis of measurement between potential highway alternatives. The design and construction of facilities to convey the larger flood events in the UFAs identified in this study, for example, may require costly solutions that will require coordination between all entities involved. These UFAs occur at various locations along the highway, and while not FEMA-regulated floodplains, they have been identified as areas where there is the potential for significant flooding, as discussed in Section 5.2.2., Urban Flooding Areas. Because of the magnitude of the flows, estimated effects to a preferred alternative will need to be carefully evaluated for the Final EIS.

9. Description of alternatives

The I-70 East Supplemental Draft EIS examines potential effects to social, environmental, and economic resources resulting from proposed improvements to I-70 between I-25 and Tower Road. Consistent with federal regulations, the Supplemental Draft EIS fully evaluates potential effects that might result from the No-Action Alternative and the Build Alternatives (Revised Viaduct Alternative and Partial Cover Lowered Alternative). The alternatives and options are presented in Table 3.

For more detail on the alternatives and their options, see Attachment C, *Alternative Analysis Technical Report.*

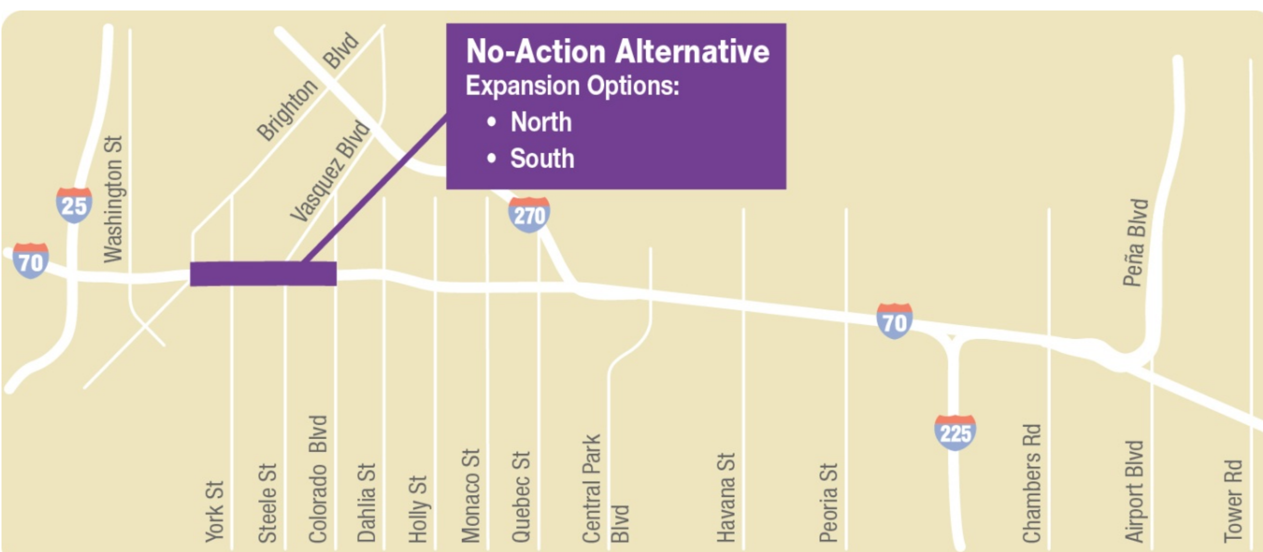
Table 3. Alternatives and Options

<table>
<tr><th colspan="2">Alternative</th><th>Expansion Options</th><th>Connectivity Options</th><th>Operational Options</th></tr>
<tr><td colspan="2">No-Action</td><td>• North
• South</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="2">Build Alternatives</td><td>Revised Viaduct</td><td>• North
• South</td><td>N/A</td><td>• General-Purpose Lanes
• Managed Lanes</td></tr>
<tr><td>Partial Cover Lowered</td><td>N/A</td><td>• Basic
• Modified</td><td>• General-Purpose Lanes
• Managed Lanes</td></tr>
</table>

No-Action Alternative

The No-Action Alternative replaces the existing viaduct between Brighton Boulevard and Colorado Boulevard without adding any capacity; the remainder of the corridor will reflect current conditions and include existing, planned, and programmed roadway and transit improvements (such as FasTracks) in the study area. The No-Action Alternative is shown in Figure 5.

Figure 5. No-Action Alternative



Build Alternatives

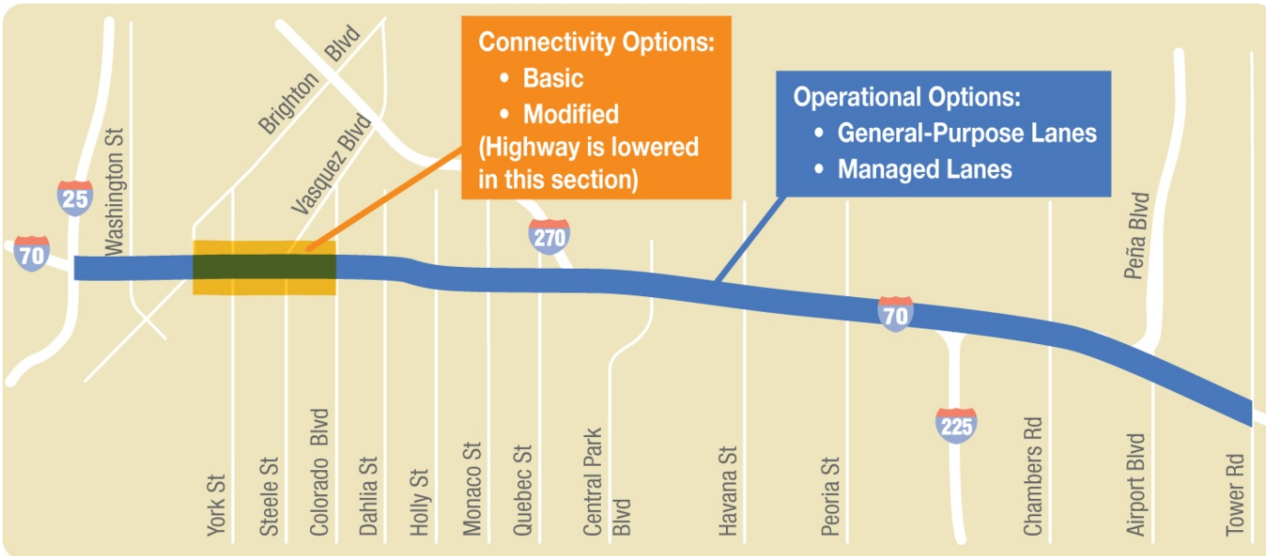
Build Alternatives add capacity to I-70 by constructing additional lane(s) or restriping between I-25 and Tower Road.

Revised Viaduct Alternative. The Revised Viaduct Alternative is shown in Figure 6. This alternative replaces the existing I-70 viaduct between Brighton Boulevard and Colorado Boulevard. It adds two additional lanes in each direction from Brighton Boulevard to Tower Road. It also adds capacity from I-25 to Brighton Boulevard.

Figure 6. Revised Viaduct Alternative

Partial Cover Lowered Alternative. The Partial Cover Lowered Alternative is shown in Figure 7. This alternative removes the existing I-70 viaduct between Brighton Boulevard and Colorado Boulevard, lowering the highway below grade in this area, while adding two additional lanes in each direction from Brighton Boulevard to Tower Road. This alternative includes a cover over the highway between Clayton Street and Columbine Street. The alternative also adds capacity from I-25 to Brighton Boulevard.

Figure 7. Partial Cover Lowered Alternative



Alternative Options

Expansion Options. Expansion Options, shown in Figure 5 and Figure 6, refer to moving the north edge of the highway north or the south edge of the highway south of the existing facility from Brighton Boulevard to Colorado Boulevard to accommodate the larger footprint resulting from standard width lanes, expanded shoulders, and construction phasing. These options apply to the No-Action Alternative and the Revised Viaduct Alternative. The Partial Cover Lowered Alternative does not include the Expansion Options because expansion of the highway can occur only on the north side due to engineering restrictions and the location of the UPRR rail yard to the south.

Connectivity Options. Connectivity Options are shown in Figure 7 and apply only to the Partial Cover Lowered Alternative. They include different frontage road and highway cover combinations. The Basic Option includes a highway cover between Clayton Street and Columbine Street, with 46th Avenue operating as a one-way road on each side of the highway (westbound on the north side and eastbound on the south side). The Modified Option removes the Steele Street/Vasquez Boulevard interchange to include an additional cover in the vicinity of Steele Street. 46th Avenue is designed as a two-way street on both the north and south sides of the highway; however, it is discontinued between Clayton Street and Columbine Street on the north side to allow for a seamless connection between Swansea Elementary School and the cover. Vehicular north/south connectivity across the highway at Josephine Street will be eliminated and replaced with a bike/pedestrian bridge. Additional connectivity and intersection improvements are discussed in Chapter 3, Summary of Project Alternatives.

Operational Options. Operational Options include two scenarios on how the additional capacity will be managed and operated. The General-Purpose Lanes Option will allow all vehicles to use all the lanes on the highway, while the Managed Lanes Option implements operational strategies (such as pricing) for the additional lanes that would be adjusted based on real-time traffic demand for vehicles that use these lanes. The additional lanes are separated with a four-foot buffer from the rest of the lanes under the Managed Lanes Option, and they have direct connections to I-225, I-270, and Peña Boulevard. Operational Options apply to the Revised Viaduct Alternative and the Partial Cover Lowered Alternative, and they are shown in Figure 6 and Figure 7.

10. Potential mitigation

Hydrologic analysis of the project alternatives used available studies to determine peak flows impacting the project. Future hydrologic studies may become available as design of the project alternatives advances. Preliminary design of the proposed storm drainage systems used available information to identify potential solutions to onsite and offsite drainage issues. Further design and analysis will be required upon selection of a preferred alternative.

The existing offsite drainage (surface flows) is not anticipated to be impacted or changed by the No-Action Alternative or the Revised Viaduct Alternative. Onsite drainage flows (within the construction limits) will be changed due to all of the alternatives. For the No-Action or the Revised Viaduct Alternatives, the increased width of the viaduct increases the amount of runoff from the I-70 viaduct. Improvements to properly address storm drainage runoff will be necessary, with specific water quality measures to conform to the MS4 requirements. Detention structures may be required to mitigate the additional width of the proposed viaduct structures. Additionally, an onsite drainage outfall system is proposed to convey runoff from the No-Action and Revised Viaduct Alternatives directly to the South Platte River north of I-70 near Riverside Cemetery and reduce the runoff draining into the existing Urban Ponding Area. This outfall will not change the boundary of the existing South Platte floodplain.

With the Partial Cover Lowered Alternative, the highway will be lowered between Brighton Boulevard and Colorado Boulevard therefore both onsite drainage and offsite drainage design will have to be implemented. The following sections discuss the offsite and onsite improvements associated with the Partial Cover Lowered Alternative.

10.1. Offsite drainage system

The Partial Cover Lowered Alternative consists of removing the I-70 viaduct between Brighton Boulevard and Colorado Boulevard and construction of proposed I-70 below existing ground elevation, referred to as lowered section. This lowered section includes a low point between near the Union Pacific Railroad crossing. The purpose of the offsite drainage system is to prevent the existing offsite flows from draining into the lowered section of I-70. The offsite drainage system is designed to convey the 100-year flow which is required for an interstate facility. The offsite drainage system is shown in Appendix C.

For the purpose of more detailed discussion, the I-70 Partial Cover Lowered Alternative alignment was divided into three sections as follows.

Section 1—Dahlia Street to Madison Street

The flow impacting this section of I-70 to the east of Colorado Boulevard was referenced from the *Park Hill Drainage Outfall Systems Plans Conceptual Design Report* (Enginuity & Matrix Design Group, 2012). The 100-year flow impacting this section of I-70 is 500 cfs. The flow will be captured in a proposed storm drain system and conveyed to the west into a proposed detention Pond 1. It should be noted that there is an existing DSDMP facility that is a 60-inch RCP located approximately 1,000 feet to the east of Colorado Boulevard that crosses under I-70. The existing RCP will remain with the construction of the I-70 project.

A series of five detention ponds are proposed in the vicinity of the Colorado Boulevard interchange (see Figure 8):

- Pond 1: Located in the southeast quadrant
- Pond 2: Located in the southwest quadrant
- Pond 3: Located in the southwest quadrant
- Pond 4: Located in the northwest quadrant
- Pond 5: Located in the northeast quadrant

Figure 8. Detention ponds in the vicinity of Colorado Boulevard

The five detention ponds are connected with equalizing culverts. The lowest outlet is located on Pond 5, which discharges into a proposed 72-inch RCP that drains to the north and connects into an existing DSDMP facility located on 48th Avenue. The purpose of the five detention ponds is to reduce/attenuate the flow discharging into the existing DSDMP facility on 48th Avenue.

Additional flow of 400 cfs from DSDMP basin 0060-00 drains into Pond 2 through a proposed connection to the BNSF Denver Market Lead. The BNSF Denver Market Lead includes a sump area that fills with runoff during large rainfall events. A proposed connection of the Market Lead to Pond 2 will provide an overflow to the sump area. The benefit of directing this flow into Pond 2 is to reduce the overflow to the west that could enter the lowered portion of I-70.

Section 2—Madison Street to York Street

The flow impacting I-70 between Madison Street to York Street is generated from local basin flow that is not collected in the existing DSDMP storm drain network. The proposed drainage facilities included in this stretch of I-70 begin in the southeast quadrant of the Steele Street interchange. An open channel section is proposed near the interchange to capture the surface flow without the need of a large complex system of inlets. A storm drain is proposed starting at the west of the Steele Street interchange and discharging into Pond 6 at York Street. An existing 72-inch RCP designed to convey the 5-year flow of 349 cfs is located at York Street that drains to the north. This facility is proposed to remain with the I-70 project. It will need to be located above the lowered section of I-70. The remaining runoff flows to Pond 6 and drains to the west into Pond 7(see Figure 9).

Section 3—York Street to South Platte River

The flow impacting I-70 between York Street and the South Platte River is referenced from the *Memorandum for I-70 PCL Montclair Drainage Basin Hydrologic Analysis* (Enginuity, February 2014). The Montclair study analyzed this stretch of I-70 with a two-dimensional model and determined the 100-year flow of 2,691 cfs would reach this section of I-70, between Brighton Boulevard and the Union Pacific Railroad.

To capture the offsite flow before it would enter the I-70 lowered section, proposed Pond 7 and a storm drain sized to convey the discharge are proposed. The purpose of Pond 7 is to capture the large surface flows draining to this area. The outlet storm drain from Pond 7 is routed to the south of the Denver Coliseum building and through the parking lot. It then follows the proposed 40th and High Street outfall system, through Globeville Landing Park and discharges into the South Platte River.

A memorandum dated January 16, 2013, was provided to Denver that documented the offsite flows used to prepare the preliminary design of the Partial Cover Lowered Alternative offsite storm drain system. The lower Montclair basin flows have been changed per the *Memorandum for I-70 PCL Montclair Drainage Basin Hydrologic Analysis* (Enginuity, February 2014). This memorandum is included in Appendix B. As additional analysis is completed by Denver or others, these offsite flows can be revised and the offsite system refined.

Figure 9. Detention ponds in the vicinity of UPRR

10.2. Onsite drainage system

The Partial Cover Lowered Alternative will replace the viaduct by a lowered section of I-70 between Brighton Boulevard and Colorado Boulevard. The lowering of this section of the roadway will create two high points: west of Brighton Boulevard on the west side and at Dahlia Street on the east side with sag between York Street and the Union Pacific Railroad. The total onsite I-70 roadway drainage area is approximately 60 acres. For the purpose of estimating how much flow can be routed to an offsite drainage system, the onsite roadway was divided into four drainage basins.

I-70 roadway drainage area from Dahlia Street to Colorado Boulevard produces an estimated 100-year flow of approximately 110 cfs. This flow is proposed to be captured progressively by an inlet and storm sewer system and routed to the proposed regional detention pond (Regional Pond 2) at the intersection of Colorado Boulevard and I-70. Minimal bypass flow should be allowed to enter the downstream basins. I-70 roadway drainage area from Brighton Boulevard to Colorado Boulevard produces an estimated 100-year flow of approximately 120 cfs. This flow is proposed to be collected progressively by an inlet and storm sewer system and routed to a proposed outfall storm sewer.

The outfall will collect the flow from the lowered section of the roadway. The storm outfall is proposed to extend from I-70 at Claude Street to the South Platte River downstream of the drop structure near Franklin Street. The onsite drainage system is shown in Appendix C. The proposed storm drain system includes approximately 3,800 linear feet of 72-inch RCP at a slope of approximately 0.20 percent. Due to the depth of this system, this pipe is expected to be constructed by tunneling.

The onsite system will discharge into a proposed detention pond that has the capacity to contain the 100-year volume and be pumped over the Burlington Irrigation Canal and discharged to the South Platte River. The emergency overflow would drain into the Burlington Irrigation Canal and will need to be coordinated with the irrigation company. A second option for consideration would be to outlet into the Burlington Irrigation Canal but this will require additional coordination with the ditch company.

11. Summary

This report represents the initial steps in identifying and resolving the drainage issues for the I-70 East alternatives. The main objectives of the study were to characterize floodplains and drainage issues along the alignments of the various alternatives and present preliminary drainage design alternatives and recommendations that improve driving safety and have minimal effects while meeting the project criteria.

There are two major drainage issues associated with the proposed highway alternatives. One is the drainage produced on the highway (onsite flows) and the other is the offsite drainage crossing the No-Action and Revised Viaduct Alternative design options. This report primarily discusses the drainage crossings, the offsite drainage, and the onsite drainage specific to the Partial Cover Lowered Alternative. All of the major drainage channels are FEMA-regulated floodplains and all improvements and new bridges or culverts may be subject to the CLOMR/LOMR process. Major drainage crossing locations have been labeled as design locations in this assessment and the existing conditions have been discussed.

With the development of a preferred alternative in the Final EIS, hydraulic models will be created to duplicate the existing FIS models. Existing- and proposed-condition models will be developed to accurately determine the floodplain effects of the proposed new structures. It is anticipated that the final structures will be designed to produce zero rise in the water surface elevations in the vicinity of the structures. The final consideration for bridge structure design will be scour countermeasure design.

Differences between the options along the Revised Viaduct Alternative and Partial Cover Lowered Alternative are substantial. They open up potential for drainage improvements along reconstructed 46th Avenue that will benefit downstream areas to a great extent. Coordination will be necessary with Denver for flood reduction benefits that stem from construction of the Partial Cover Lowered Alternative. The differences between the No-Action Alternative and Revised Viaduct Alternative are minimal. The differences primarily include increased system capacity related to the increased impervious area.

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Attachment M – Appendix A
Drainage Design Criteria Memorandum

I-70 EAST CORRIDOR
Environmental Impact Statement

MEMORANDUM

TO: R.A. Plummer

FROM: Dane Dasent

CC:

DATE: April 27, 2005 (Revised June 7, 2007)

SUBJECT: Drainage Design Criteria

1.0 PROJECT BACKGROUND AND DESCRIPTION

The I-70 East Corridor Environmental Impact Statement (EIS) is a joint effort by the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) in cooperation with the Colorado Department of Transportation (CDOT), Regional Transportation District (RTD), and the City and County of Denver (Denver). The intent of the EIS is to identify multi-modal transportation improvements along the I-70 East Corridor including rapid transit service between downtown Denver and Denver International Airport (DIA).

2.0 APPLICABLE CRITERIA

This document provides a summary of drainage criteria for the project, and is not intended to be a comprehensive list of all current and future criteria which may be applicable. The I-70 East Corridor is a large, complex project that traverses multiple cities, counties, and governmental agency jurisdictions, and omission of any design criteria published by any such entity does not imply that those criteria are not applicable to the project.

It is assumed that all drainage design work associated with the I-70 East EIS will be performed in compliance with the following:

1. CDOT - *Drainage Design Manual (2004)*
2. Draft RTD Light Rail Design Criteria (2005)
3. RTD *Guidelines and Criteria for Bus Transit Facilities* (2005)
4. Draft RTD *Commuter Rail Design Criteria* (2005)
5. CDOT *MS4 Guidelines*
6. FHWA - *Roadside Design Guide*
7. City and County of Denver - *Storm Drainage Design and Technical Criteria Manual*
8. Urban Drainage and Flood Control District – *Urban Storm Drainage Criteria Manual Vol. 1-3*
9. City of Aurora- *Storm Drainage Design & Technical Criteria*
10. City of Commerce City – *Drainage Criteria Manual*
11. Adams County – *Storm Drainage Design and Technical Criteria Manual*
12. Arapahoe County – *Storm Drainage Design and Technical Criteria Manual*
13. Union Pacific (UP) Railroad– *Guidelines for Design of Highway Separation Structures Over Railroad (Overhead Grade Separation)*

14. UP – *Guidelines for Design and Construction of Grade Separation Underpass Structures*
15. AREMA *Manual for Railway Engineering* (2004)

In addition, stormwater requirements for the following will be incorporated as necessary:

1. Colorado Water Conservation Board (CWCB)
2. Colorado Department of Public Health and Environment (CDPHE).

As a rule, unless otherwise noted, in locations subject to the design criteria of two or more entities, the most stringent criteria will be applied to the project design.

3.0 PERMITS AND APPROVALS

Various permits may be necessary for construction and operation of this project. The listing herein is not all-inclusive, and all permits required in order to perform the work shall be determined during the design phase of the project.

3.1 NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM STORMWATER DISCHARGE PERMIT

A Stormwater Discharges Associated with Construction Activity Permit from the CDPHE and the local jurisdictional entity (e.g., Denver, Aurora, Adams County) shall be obtained at the time of construction of the project per Section 402 of the Clean Water Act. Construction documents shall include a stormwater management plan detailing Best Management Practices (BMP's) to control:

(i) Erosion and sedimentation, and;
(ii) The discharge of any pollutants that may enter stormwater and be transported to receiving waters.

Any new stormwater system in the project shall meet or exceed goals for discharge of runoff constituents (where these goals have been established) through the use of nonstructural and structural BMP's.

3.2 GROUNDWATER DISCHARGE PERMIT

Any dewatering of groundwater during construction shall be in accordance with the Water Quality Control Division (WQCD), Colorado Discharge Permit System (CDPS) Application for Construction Wastewater Discharge, to be obtained from the CDPHE.

Any permanent groundwater diversion shall be permitted, in accordance with WQCD, CDPS Application. The water quality standard that governs this discharge is that of the receiving water as evaluated by the WQCD. All information needed to assist WQCD in their evaluation and setting of a water quality standard for this permit shall be provided as and when required.

3.3 SECTION 404 PERMIT

A Section 404 Permit may have to be obtained for this project for construction that discharges dredged and fill materials in jurisdictional wetlands or Waters of the United States. The location of wetlands within the project area shall be delineated in accordance with U.S. Army Corps of Engineers (COE) approved procedures. Stipulations of this permit shall be incorporated into the construction documents. A Section 401 water quality certification may also be required from the State in order to obtain the Section 404 permit.

3.4 FLOODPLAIN USE PERMIT

The location of floodplain areas shall be delineated from the most current Flood Insurance Rate Maps (FIRM) published by Federal Emergency Management Agency (FEMA). A permit shall be obtained from the Floodplain Administrator of the affected jurisdiction for any construction within areas delineated as Zone A, AE, AH, AO, or A99 on FIRM. A Conditional Letter of Map Revision/Letter of Map Revision (CLOMR/LOMR) process may have to be undertaken with FEMA if the proposed construction raises the regulatory base flood elevation of any floodplain.

3.5 SEWER USE AND DRAINAGE PERMITS

Sewer Use and Drainage Permits (SU&DP's) shall be obtained for all connections, including temporary, into any sanitary sewer and storm sewer systems that are owned by Denver, Wastewater Management Division, or that discharge into storm or sanitary sewer systems owned by Denver, Wastewater Management Division, outside the CDOT right-of-way (ROW). Denver, Wastewater Management Division, also requires that SU&DP's shall be obtained for all:

1. cutoffs of services lines
2. abandonment of sewers (sanitary or storm)
3. minor modification (manholes and inlets only)
4. new or relocated service connections

SU&DP's shall be obtained from other affected local jurisdictions, as required.

3.6 MUNICIPAL SEPARATE STORM SEWER (MS4) PERMIT

Implementation of certain Municipal Separate Storm Sewer (MS4) Program elements within the Project limits shall be undertaken as necessary, these include, but shall not be limited to:

1. Illicit discharges into the storm sewer system
2. Maintenance of structural controls

3.7 RAILROAD AND/OR IRRIGATION COMPANY APPROVALS

Approvals may be required for any work that affects existing railroad tracks and/or facilities, and should be obtained through discussions with the affected railroads. In cases where the proposed construction requires modifications to, or replacement of existing irrigation ditches, canals or other structures, approval shall be obtained from the irrigation company that owns the ditch or property.

4.0 WATER RIGHTS

The Colorado State Engineer's Office (CSEO) has stated that any permanent or temporary diversion of groundwater occurring within a project for the purpose of dewatering structures has the potential for material injury to a water right. No activities shall be performed that could be cause for material injury to a water right. The CSEO will determine the extent that material injury from a water right does or does not occur from such activities. Further, as part of the groundwater discharge permitting requirements as required by the CSEO, review documentation demonstrating that the requirements of Colorado Water Law have been met shall be provided to the CSEO.

5.0 HYDROLOGY

The rational method for shall be used to determine the runoff from small basins (under 90 acres) and peak runoff for basins greater than 90 acres shall be determined using the Colorado Urban Hydrograph Procedure (CUHP). In addition, hydrology from recent CDOT, Denver and UDFCD projects may be used, if applicable. Tables 1.a and 1.b summarize the design frequencies to be used on this project.

Table 1.a
Summary of Design Criteria for Highway Hydrology

	Drainage Type	Design Frequency	Jurisdiction	Comment
Cross Drainage & Bridges	Multi-lane Roads (Including Interstates)	100-year	CDOT	CDOT requires 50-year in this segment of I-70 however local municipalities require 100-year design frequency.
	Culvert Outlet Scour Protection	10-year	CDOT	
	Bridge Opening Size	100-year	CDOT	
	Bridge Foundation Scour Protection	500-year	CDOT	
Parallel Drainage	Roadway Overtopping and Revetment	50-year		Same as cross drainage
	Roadway Overtopping and Revetment	50-year		Same as cross drainage
	Side Drains	10-year		Water shall not flow onto the highway at a greater probability than applies to cross drainage.
Storm Drains	Major System	100-year		
	Minor System	5-year		

As noted in the comments above, CDOT *Design Criteria* only requires a 50-year design frequency for this segment of I-70. However, the more stringent requirement comes from the local municipality criteria which require no overtopping of major arterials during the 100-year event. In general, local streets and minor arterials are allowed to overtop to a maximum depth at the crown of the street of 6-inches. New culverts and replacement culverts will be sized for the 100-year event.

Table 1.b
Summary of Design Criteria for Transit Hydrology

	Drainage Type	Design Frequency	Jurisdiction	Comment
Cross Drainage, Bridges & Stations	LRT Trackway	100-year	RTD	
	CR Trackway	100-year	RTD	
	Bridge Deck Drainage	100-year	RTD	
	Bridge Opening Size	100-year	RTD	
	Station Platforms	50-year	RTD	
Park-n-Ride & Bus Transit Facilities	Parking Areas & Roadways Major Storm	100-year		Local Agency if more restrictive
	Parking Areas & Roadways Minor Storm	5-year		Local Agency if more restrictive
	Detention Storage Minor Storm	10-year	RTD	Local Agency if more restrictive
	Detention Storage Major Storm	100-year	RTD	Local Agency if more restrictive
	Culverts	5-year	RTD	Local Agency if more restrictive
Storm Drains	Major System	100-year		
	Minor System	5-year		

RTD bridge deck drainage shall be designed in accordance with CDOT *Bridge Design Criteria* and FHWA publication HEC-21, "*Design of Bridge Deck Drainage*". On bridges where the track is fixed directly to the bridge deck surface, surface flow on the deck shall not be above the bottom of the rail at any location on the deck, and all flows will be intercepted during the 100-year storm so that no gutter flows cross the approach slabs. In cases where the track is not is fixed directly to the bridge deck surface, flows crossing the approach slabs will be limited to 0.2 cfs during the 5-year event.

6.0 MAJOR DRAINAGEWAYS

The I-70 East Corridor crosses or parallels several major drainageways. The major drainageways include the South Platte River, Sand Creek, First Creek, Second Creek, Third Creek, Irondale Gulch and Westerly Creek. In addition, the Highline Irrigation Canal also crosses the Peña Boulevard Corridor.

FEMA regulated Zone A and Zone AE floodplains (floodplains with base flood elevations), have been established for the major drainageways along the I-70 East Corridor. Zone A floodplains are floodplains which have been determined by approximate methods and for which no base flood elevations have been determined. Zone AE floodplains have been determined by accurate methods and have associated base flood elevations and floodways.

In addition to the channel criteria listed in Section 8 of this memorandum, the following floodplain criteria shall also apply:

1. Embankment encroachment in any stream channel or floodplain should be avoided.
2. If encroachment into a floodplain cannot be avoided, the hydraulic effects of floodplain encroachments shall be evaluated over a full range of frequency based peak discharges for the 2-year design flood and the 100-year recurrence intervals on any major highway facility.
3. If relocation of the stream channel is unavoidable, the cross-sectional shape, meander, pattern, roughness, sediment transport, and slope shall conform to the existing conditions insofar as practicable. Some means of energy dissipation or grade control may be necessary when existing conditions cannot be duplicated.
4. Streambank stabilization shall be provided, when appropriate, as a result of any stream disturbance such as encroachment and shall include both upstream and downstream banks as well as the local site.
5. FEMA approvals may be required for work in major drainageways.

7.0 BRIDGES

Final design selections for bridges on the I-70 East Corridor should consider the maximum backwater allowed by the National Flood Insurance Program (NFIP), unless exceedence of the limit can be justified by special hydraulic conditions. New structures will conform to FEMA regulations for sites covered by the NFIP. An increase in backwater greater than one foot may be allowed for non NFIP crossings only if adequate justification is provided to document that the design is the only practicable alternative, and that the design will cause minimal impacts.

The following criteria and guidelines will be used for the design of bridges on this project:

1. The final design should not significantly alter the existing flow distribution in the floodplain. Backwater will not cause increased flood damage to property upstream of the crossing.
2. The “crest-vertical curve profile” is the preferred highway and transit, bridge crossing profile when allowing for embankment overtopping at a lower discharge and for adequate deck drainage.
3. Sag vertical curves can cause deck drainage to pond and ice up on the bridges and should be avoided.
4. Horizontal curve transitions on highway bridges cause water to flow across lanes and should not be located on a highway bridge because of icing and hydroplaning problems.
5. Clearance or freeboard should be provided between the low girder and the design water surface to allow for the passage of ice and debris.
6. The design capacity of any bridge will be the flow that will pass through the bridge with adequate freeboard and without track or roadway overtopping.
7. Degradation or aggradation of the river as well as contraction and local scour should be estimated, and appropriate positioning of the foundation, below the total scour depth if practicable, shall be included as part of the final design.
8. Velocities through the structure(s) will not damage either the highway or transit facilities

or increase damages to adjacent property.

9. Pier spacing and orientation, and abutment location shall be designed to minimize flow disruption and potential scour. Bridge piers should not be placed in the main channel area. Foundation design and/or scour countermeasures shall be made to avoid failure by scour.
10. The final design should produce minimal disruption of ecosystems and values unique to the floodplain and stream.
11. For highway bridges, provide a level of traffic service compatible with that commonly expected for the class of highway and compatible with projected traffic volumes.
12. For transit bridges, provide a level of protection to ensure that rail operations can continue without interruption.
13. Design choices should support costs for construction, maintenance, and operation including probable repair and reconstruction and potential liability that are affordable.

Freeboard for all bridges (transit and highway) will be provided according to the following equation:

Freeboard = $0.089\, Q^{0.3} + 0.026\, V^2$ *(CDOT Drainage Design Manual, 2004)*

Where Q is the design discharge in cubic feet per second (cfs) and V is the mean velocity of the design flow through the bridge in ft/s. The maximum velocity is 16 ft/s.

8.0 CHANNELS

All channel improvements will be designed per Section 8 of the CDOT *Drainage Design Manual* and the Urban Drainage and Flood Control District's *Drainage Criteria Manual (2001)*.
Table 2 summarizes the design criteria as outlined in the CDOT *Drainage Design Manual* and the Urban Drainage and Flood Control District's *Storm Drainage Criteria Manual (2001)*.

Table 2
Summary of Design Criteria for Channels

Design Item	Criteria	Jurisdiction
Ditch Lining Design Discharge	10-Year Frequency (permanent) 2-Year Frequency (temporary)	CDOT
Side slopes	2:1 or flatter with riprap lining 4:1 or flatter for vegetated	CDOT
Bend Radius	2 x top width or 100 ft min.	UDFCD
Freeboard	As specified in CDOT equation, or 1 foot minimum	CDOT
Flow velocity (max.)	5.0 fps for erosive soils 7.0 fps for non-erosive soils 12.0 fps for riprap lined channels	Min. velocity must be greater than 2.0 fps.
Froude Number (max.)	< 0.5 for erosive soils < 0.8 for non-erosive soils	UDFCD
Max. Channel Slope	0.6% (grass lined) 1.0% (riprap lined)	UDFCD
Trickle Channel Design	Shall be based on UDFCD criteria	CDOT

9.0 CULVERTS

Culvert sizes will adhere to the minimum culvert diameters presented in the local municipality's storm drainage design and technical criteria. Transit facilities culverts will adhere to the criteria specified by RTD for LRT, AREMA for CR, or the UP for heavy rail lines as applicable.

The minimum size for cross-culverts under the interstate will be 36-inch diameter (or equivalent). Minimum sizes for culverts under other streets will be per local jurisdiction criteria. Culvert skew will not be less than 45 degrees and culvert end treatments will be used as recommended in the Drainage Criteria Manual. Flared end sections will be used for smaller culverts. Culverts 42 inches or larger will include type "S" headwalls. Full headwalls and wingwalls will be installed on any culvert 96 inches or larger. Table 3 summarizes the design criteria as outlined in the Drainage Design Manual.
The minimum size for culverts under trackbeds and within transit facilities shall be 18-inch diameter, unless larger sizes are specified in the drainage criteria of the jurisdiction in which the facilities are to be constructed.
Design criteria for culverts are summarized in the following Table 3.

Table 3
Summary of Design Criteria for Culverts

OWNER	**Culvert Type**	**Minimum Pipe Size**	**Comments**
RTD	All Culverts	18"	
CDOT	Cross Culverts	36" (or equivalent)	
	Side Drain	18"	
	Median Drain	18"	
	Median Drain to cross culvert	15"	

OWNER	**Culvert Size**	**Maximum Headwater to Diameter Ratio (H_w/D)**	
RTD	All Sizes (50-year)	1.5	H_w/D greater than 1.5 may be allowed if energy dissipation is provided.
CDOT	< 36"	2.0	
	36" - 60"	1.7	
	> 60" to < 84"	1.5	
	84" to 120"	1.2	
	≥ 120"	1.0	

RTD & CDOT	**Allowable Velocities**	**Minimum Flow Velocity**	
		3.0 feet/sec	
		Maximum Flow Velocity	
		16.0 feet/sec	
	Culvert Size	**End Treatments**	
	Culvert diameter < 42”	Use end section	No plastic end sections
	42” ≤ Culvert diameter < 96”	Use Type ‘S’ headwall	
	96” ≤ Culvert diameter	Use full headwall and wingwalls	

10. INLETS AND STORM DRAINS

HIGHWAY

The minimum size for storm drains range from 15 inches for median and curb inlet drains connecting to cross culverts and trunk lines, to 18-inches for side drains, median drains, storm drain trunk lines, and irrigation crossings, to 36-inch pipes for cross culverts. The following criteria shown in Table 4.a shall apply to roadway spread widths, inlet design and storm drain design for the highway facilities. It should be noted that per the City of Aurora drainage criteria, only Type R modified curb-opening inlets are accepted within the public ROW or for public ownership.

Table 4.a
Summary of Design Criteria for Roadway, Inlets and Storm Drains

	Design Item / Size	Criteria	Jurisdiction	Comments
Spread Width – Minor Storm	Interstate	Shoulder		5-Year Design Frequency
	Arterials (< 45 mph)	Shoulder + 4 ft with at least two 10 foot lanes free of water		5-Year Design Frequency
	Arterials (> 45 mph)	Shoulder with at least two 10 foot lanes free of water		5-Year Design Frequency
	Collectors (< 45 mph)	½ Driving Lane with at least one 10 foot lane free of water		5-Year Design Frequency
	Collectors (> 45 mph)	Shoulder + 4 ft with at least one 10 foot lane free of water		5-Year Design Frequency
	Local Streets	No curb overtopping		5-Year Design Frequency
Ditch Encroachment – Minor Storm	Interstate	No encroachment on street shoulder		5-Year Design Frequency
	Arterials (< 45 mph)	No encroachment on street shoulder		5-Year Design Frequency
	Arterials (> 45 mph)	No encroachment on street shoulder		5-Year Design Frequency
	Collectors (< 45 mph)	No encroachment on street shoulder		5-Year Design Frequency
	Collectors (> 45 mph)	No encroachment on street shoulder		5-Year Design Frequency
	Local	No encroachment on shoulder area		5-Year Design Frequency
Street Capacity – Major Storm	Buildings	No building inundation		
	Depth of Water at Crown	< 6 inches		
	Interstate Highways	Spread shall not go beyond 4 feet into travel lane		
	At Sump	No road closure allowed unless alternate route available.		
Street Grades	Minimum Grade	0.3 percent		
	Maximum Grade	N/A		

Inlet Capacity Reduction	Less than 20 sq. in. opening	40 percent		Grated Inlets
	20-50 sq. in opening	50 percent		Grated Inlets
	60 sq. in. and greater	70 percent		Grated Inlets
	5’ Type R	88 percent	Adams County	
	10’ Type R	92 percent	Adams County	
	15’ Type R	95 percent	Adams County	
	Grated Type 13	50 percent	Adams County	
	Grated Type C (sump)	50 percent	Adams County	
	Combination Type 13	66 percent	Adams County	
Minimum Pipe Sizes	Laterals to trunk lines or culverts	15”		
	Trunk lines	18”		
	Cross culverts	24”		
Storm Drain Velocities	Min. Velocity	3 fps		
	Max. Velocity	18 fps		
Storm Drain Manhole Spacing	15" to 36”	400 ft		
	All pipes sizes	500 ft	City and County of Denver	
Manhole Sizing	30” pipe or less	4’ diameter	City and County of Denver	
	33” to 36” pipe	5’ diameter	City and County of Denver	
	42” pipe and larger	Type B or P Manhole	City and County of Denver	

TRANSIT

The minimum sizes for storm drains and culverts are 15 inches and 18 inches respectively. All storm drains and culverts crossing under trackbeds shall be at minimum Class V RCP. Storm drains and culverts in park-n-ride facilities and in other RTD facilities that are not under tracks shall be at minimum Class III RCP. Per RTD's LRT design criteria, the tops of all storm drain and culvert pipes crossing under trackbeds shall be a minimum of 60 inches from to of rail to top of pipe. For CR see AREMA for the required clearance. For CR follow AREMA standards for culverts crossing under trackbeds, this includes encasement of the culvert.

Inlets on or adjacent to LRT and CR tracks (including grates and inlet boxes) shall be grate inlets designed for H-20 loading. Ballast screens should be used to prevent ballast rock from entering the storm drain system. Inlets within RTD facilities that are not on or adjacent to LRT and CR tracks shall be bicycle safe, and inlets in pedestrian areas shall be heel-proof and non-slip. Inlets in curbed areas within bus transit facilities shall be Type R inlets, as modified by RTD standard drawings, and shall be designed in accordance with local jurisdictional requirements. Underdrains shall be used on or adjacent to trackbeds where standard ditch sections are not practicable. Underdrains shall be perforated concrete pipe or perforated plastic pipe only. For lengths of underdrain less than 500 feet, the minimum underdrain size shall be 6 inches, and for lengths equal to or greater than 500 feet, the minimum size shall be 8 inches. The following criteria, shown in Table 4.b shall apply to inlet design and storm drain design for the transit facilities.

Table 4.b
Summary of Design Criteria for Transit Inlets and Storm Drains

	Design Item / Size	Criteria	Jurisdiction	Comments
Inlet Operation and Ponding Depths	Buildings	No building inundation		Major and minor storms
	Maximum ponding depth at inlets	6 inches	RTD	Minor Storm
	Maximum ponding depth at inlets	9 inches	RTD	Major Storm
	Maximum ponding depth in parking lots	None	RTD	Minor Storm
	Maximum ponding depth in parking lots	9 inches	RTD	100-year storm
Inlet Capacity Reduction	Less than 20 sq. in. opening	40 percent		per Local Jurisdictional Criteria
	20-50 sq. in opening	50 percent		per Local Jurisdictional Criteria
	60 sq. in. and greater	70 percent		per Local Jurisdictional Criteria
	5' Type R	88 percent		per Local Jurisdictional Criteria
	10' Type R	92 percent		per Local Jurisdictional Criteria

	15' Type R	95 percent		per Local Jurisdictional Criteria
Minimum Pipe Sizes	Laterals to trunk lines or culverts	15 inch	RTD	
	Trunk lines	18 inch	RTD	
	Cross culverts	18 inch	RTD	
	Underdrains shorter than 500 ft.	6 inch	RTD	Perforated concrete or plastic pipe only
	Underdrains longer than 500 ft.	8 inch	RTD	Perforated concrete or plastic pipe only
Storm Drain Velocities	Minimum Velocity	3 fps		per Local Jurisdictional Criteria
	Maximum Velocity	22 fps		per Local Jurisdictional Criteria
Storm Drain Manhole Spacing	15" to 36"	400 ft		per Local Jurisdictional Criteria
	24" and greater	500 ft		per Local Jurisdictional Criteria
Manhole Sizing	18" pipe	4' diameter		per Local Jurisdictional Criteria
	21" to 36" pipe	5' diameter		per Local Jurisdictional Criteria
	36" pipe and larger	6' diameter		per Local Jurisdictional Criteria

In addition to the above criteria, the following guidelines shall also apply:

10.1 Superelevation

To prevent cross flow on highways, inlets are required ten feet before the point where roadway cross slopes begin to superelevate toward the opposite side. In addition, 100 percent of the 5-year storm runoff will be intercepted at superelevation transitions where flows could pond or cross roadway.

10.2 Sump Locations

Inlets located at the low points of sag vertical curves on highways shall be designed to limit spread width to four feet beyond the edge of shoulder for the 100-year storm. Inlets shall be designed for the 100-year storm for the light rail (LRT) or commuter rail (CR) tracks. Type R inlets on grade shall be avoided in curbed areas within bus facilities. Sump locations on highways require flanking inlets on each side of the sump to provide relief should the sump inlet clog. The flanking inlets shall be located so that the design criteria for ponding and spreadwidth are met even if the sump inlet is completely clogged. Flanking inlets shall be located at sag vertical curves of I-70 per HEC-22.

10.3 Intersections

At intersections with side streets, inlets shall be located at tangent curb sections on the upstream sides of the intersection, to ensure that 100 percent of cross flows from the side streets is intercepted during the minor storm. No cross street flow will be allowed to enter a state highway.

10.4 Edge Treatment at Fill Slopes

In areas where in excess of 50-feet of pavement or trackbed width contributes runoff to a fill slope, or where the fill slope is steeper than 4 H : 1 V for transit alignment embankments, and 3 H : 1 V for highway, a drainage barrier (Type 4 or 7 guardrail), shall be used to collect flow from the roadway or trackbed and convey it to inlets or rundowns in an effort to prevent erosion of the embankment. Alternatively, the fill slopes may be covered with an approved erosion control blanket or bonded fiber material.

10.5 Ditches

Roadside Ditches

Roadside ditches, where used, shall be designed to capture and convey the 50-year design storm. The geometric layout shall be in accordance with the American Association of State Highway and Transportation Officials (AASHTO), *Roadside Design Guide*, and shall consider safety, maintenance, landscaping, and aesthetics. The capacity shall be determined using Manning’s equation and flexible channel linings shall be designed in accordance with HEC-15. For roadside ditches along I-70, the design water surface elevation shall not exceed the edge of shoulder for the 50-year event.

Trackside Ditches

Trackside ditches shall be constructed where possible to convey flows parallel to the CR or LRT tracks. Trackside ditches shall be constructed at a minimum grade of 0.3 percent and shall be designed to ensure that the water surface elevations in the ditches do not exceed the top of subgrade (bottom of ballast) of the tracks in the 100-year storm. The geometric layout shall be in accordance with the American Association of State Highway and Transportation Officials (AASHTO), *Roadside Design Guide,* and shall consider safety, maintenance, landscaping, and aesthetics. The capacities shall be determined using Manning’s Equation and flexible channel linings shall be designed in accordance with HEC-15.

10.6 Bridge Deck Drainage

Bridge deck drainage systems are required for highway bridges, and inlets shall be located to limit spreadwidths due to the major and minor design storms to allowable values.
Bridge deck drainage systems are required for CR and LRT bridges to limit ponding depths to the bottom of rails during the 100-year storm. Inlets shall be placed to limit the quantity of flow across expansion joints to less than 0.2 cfs for the 5-year event. Gutter flows at both ends of bridges shall

be intercepted. Storm water flowing toward the bridge shall be intercepted before the approach slab. Storm water leaving a bridge shall be intercepted before leaving the approach slab. The water intercepted shall be directed to an appropriate outfall.

Bridge deck drainage for highway and transit bridges shall be designed in accordance with HEC-21. All deck drain inlets shall be grated, bicycle safe and shall be rated for H-20 loading. The drainage system shall be compatible with the structural reinforcement, components, and aesthetics of the bridge. Outfalls shall be positioned to avoid corrosion of structural members, erosion of embankments, and splash onto moving traffic (vehicular and train) and sidewalk areas below the bridge. Downspouts shall be galvanized steel pipe 10-inch minimum diameter for bridge drains and shall meet the requirements of American Society for Testing Materials (ASTM) ASTM A53, and shall be standard weight (Sch. 40). Downspout pipe shall be hot dipped galvanized after fabrication. Galvanizing shall meet the requirements of AASHTO M111. Metal used in the manufacture of castings shall meet the requirements of ASTM A48, Class 35B. Cleanouts shall be provided for all downspout systems.

10.7 Manholes, Vaults and Junction Structures

Manholes and junction structures shall be incorporated into the storm drainage system design to provide access for inspection, cleaning, and maintenance. Manholes shall be required at all junctions, drops and grade changes. Manholes shall be provided at any change in direction greater than 2.5 degrees and at the beginnings and ends of curved alignments. Inlets shall be used in lieu of manholes where feasible. Rims shall be constructed from 1/4 inch to 1/2 inch below finished grade and level. Manholes shall not be located in the I-70 mainline or ramp travel ways.

10.8 Connections to Existing Systems

Plans and specifications for connections with existing storm systems shall be reviewed by the agency having jurisdiction over the existing facility being joined. Hydraulic calculations shall demonstrate that the receiving system is not adversely impacted by the proposed discharges.

10.10 Pump Stations

The use of pumping stations shall be permitted only where stormwater removal by other means is not feasible. At a minimum, pump stations shall be designed for the 50-year, two hour event. The FHWA publication, *"Manual for Highway Storm Water Pumping Stations"*, Volumes 1 and 2 shall be used for pump station design. The extent of the 100-year storm shall be determined, and safeguards against flooding shall be provided. A storage reservoir shall be incorporated within the pump station design. The maximum water level within this storage chamber shall be no higher than two feet below the lowest track or pavement elevation. The configuration shall provide for screening out debris and a minimum of three pumps. Pump equipment and controls shall be explosion proof, corrosion resistant and appropriate for the application. Backup systems for power, control and pumping shall be provided. The design shall include access for ordinary maintenance, provisions for replacing pumps, and a minimum of two parking spaces. The pump house shall have locked doors, a fence and gate for security, and an adequate ventilation system. The design shall eliminate the need for confined space entry as defined by Occupational Safety and Health Association (OSHA) and National Institute for Occupational Health and Safety (NIOSH) where possible. The site layout shall address mitigation of aesthetics and noise. The installed equipment shall be certified and tested prior to being placed in service. The design shall include operation and maintenance manuals for the facility. Pump stations are not permitted without prior approval from RTD.

10.11 Irrigation Facilities

Stormwater shall not be discharged to irrigation ditches. Where construction affects existing irrigation facilities, approvals for modifications to existing irrigation facilities shall be obtained from the owner of such facilities.

11. DETENTION AND WATER QUALITY FACILITIES

Detention facilities for park-n-rides, station parking lots and bus transit facilities will be designed according to local jurisdictional criteria for detention. Generally detention sizing requirements are based on the 10-year and 100-year storms. Detention ponding may extend into parking areas to a depth of 9 inches during the 100-year storm however such ponding may not extend into areas designated for handicap use.

Detention facilities for parking lots other than within transit facilities will be designed such that developed peak flows do not exceed existing (historic) peak flows.

Sizing will be based on Chapter 12 of the CDOT *Drainage Design Manual*, the local municipality's storm drainage design and technical criteria, and the UDFCD criteria. If practical, all drainage from the interchanges will be routed through a water quality facility sized according to the local municipality's storm drainage design and technical criteria
The use of underground detention storage should be avoided unless all other detention options prove unfeasible.

Water quality storage will also be accounted for in the detention facilities for the parking lots. Existing cross drainage will be allowed to "*pass through*" and will not enter the water quality or detention systems.

12. EROSION CONTROL

Erosion control for I-70 shall be designed in accordance with the 2002 CDOT publication "*Erosion Control and Stormwater Quality Guidelines*".

Erosion control for transit facilities shall provide best management practices (BMP's) during construction, and these shall be designed in accordance with the technical standards and requirements of the local jurisdiction in which the facilities are to be located.

A Storm Water Management Plan (SWMP) shall be provided in accordance with the State of Colorado General Permit for Stormwater Discharges Associated with Construction Activities.

Attachment M – Appendix B
Summary of Existing Studies and Flows

Memo

To:	Frank Kemme, CCD		
From:	Josh Hollon PE, CFM, Atkins		
cc:	Carrie Wallis, Atkins	**Date:**	January 16, 2013
Ref:	I-70 EIS, CCD offsite flows		
Subject:	I-70 Offsite Flow Summary		

1.0 Introduction

The Colorado Department of Transportation (CDOT) is evaluating alternatives to improve I-70 between I-25 and Tower Road. The purpose of the project is to improve eastbound and westbound highway safety and mobility in the project area. A Environmental Impact Statement (EIS) is currently being developed for the project improvements including identification of project alternatives and associated impacts. One alternative includes a "Partial Covered Lowered" (PCL) section of I-70 between Brighton Boulevard and Colorado Boulevard. This PCL section lowers the elevation of I-70 approximately 40 to 50 feet below existing ground elevations and would impact existing drainage conditions for the area.

The purpose of this memorandum is to provide a summary of the offsite discharges that cross I-70 and affect proposed drainage systems for the I-70 PCL improvements.

2.0 Project Impacts

The PCL section lowers the elevation of I-70 between Brighton Boulevard and Colorado Boulevard and would intercept existing surface runoff from the City and County of Denver (CCD) draining from south of I-70. Existing CCD storm drain systems do not provide adequate capacity to capture and convey the 100-year runoff from the drainage areas south of I-70. Currently, I-70 is a viaduct and located above the existing ground. Runoff from the drainage areas south of I-70 flows under the I-70 viaduct and drains to the South Platte River. However, the PCL alternative would create a lowered section of I-70 and would capture the surface runoff from the drainage areas to the south. To eliminate the potential flooding of the PCL section, additional storm drainage systems are required to capture and convey the 100-year surface runoff prior to reaching the PCL section. The PCL section crosses two studied drainage areas that would contribute surface runoff to the PCL section; Lower Montclair and Lower Park Hill.

2.1. Lower Montclair Basin

The Lower Montclair basin is located south of I-70 and extends southeast to approximately the intersection of E Alameda Avenue and S Quebec Street. The basin drains south to north and surface runoff crosses I-70 between Brighton Boulevard and York Street.

2.2. Lower Park Hill Basin

The Lower Park Hill basin is located south of I-70 and extends southeast to approximately the intersection of E 40th Avenue and N Dahlia Street. The basin drains south to north and surface runoff crosses I-70 near Milwaukee Street, Steele Street, and just east of Colorado Boulevard

3.0 Previous Studies

These basins have been studied by CCD and calculated 100-year surface flows from these previous studies have been used to prepare a preliminary offsite drainage system to capture and convey the offsite surface runoff prior to reaching the PCL section of I-70. As future studies are developed for these areas, the preliminary offsite drainage system can be revised.

3.1. Lower Montclair

Enginuity prepared a Memorandum, dated August 27, 2010, RE: Sanitary and Storm Drainage Master Plan FasTracks Interface Lower Montclair Street Flow Criteria, that prepared a FLO-2D analysis of the surface flows from the Lower Montclair basin including analysis of the surface flows near I-70. Enginuity added an additional FLO-2D cross section at I-70 to calculate the surface overflows that may be captured by the PCL alternative. Cross section 3 of their FLO-2D analysis calculated approximately 4,000 cfs crossing I-70 at Brighton Boulevard and York Street. This 4,000 cfs was used to develop the preliminary offsite drainage system for the PCL alternative. A copy of the Enginuity FLO-2D figure is attached to this Technical Memorandum.

3.2. Lower Park Hill

Enginuity also prepared the Park Hill (North of Smith Road) Drainage Outfall System Plan, Conceptual Design Report, dated January 24, 2012. This report included a FLO-2D analysis of the surface flows from the Lower Park Hill basin near I-70. The FLO-2D analysis included two cross sections at I-70 which calculated the surface flows that could be captured by the PCL alternative. Cross section 1 is located near Steele Street and calculates approximately 400 cfs crossing I-70. Cross section 2 is located just east of Colorado and calculates approximately 500 cfs. The calculated 400 cfs at Steele Street and 500 cfs just east of Colorado were used to develop the preliminary offsite drainage system for the PCL alternative. A copy of the Enginuity report Figure 2 is attached to this Technical Memorandum.

4.0 Summary

The I-70 EIS is not preparing additional hydrologic analysis of this area. Instead, it utilizes the available studies and relies on their calculated surface flows to prepare the PCL offsite storm drainage system. The PCL offsite storm drainage system uses the 4,000 cfs calculated in the Lower Montclair study and applies that flow between Brighton and York Street. The PCL offsite storm drainage system also uses the 400 cfs and 500 cfs from the Lower Park Hill study and applies those flows at Steele Street and just east of Colorado Boulevard.

Per our on-going coordination efforts with CCD, it is our understanding that additional studies may be completed in the future and opportunities to reduce the peak flows reaching I-70 will be investigated. As CCD analyzes these areas and flow reductions are identified, the design flows for the I-70 PCL offsite drainage system may be reduced.

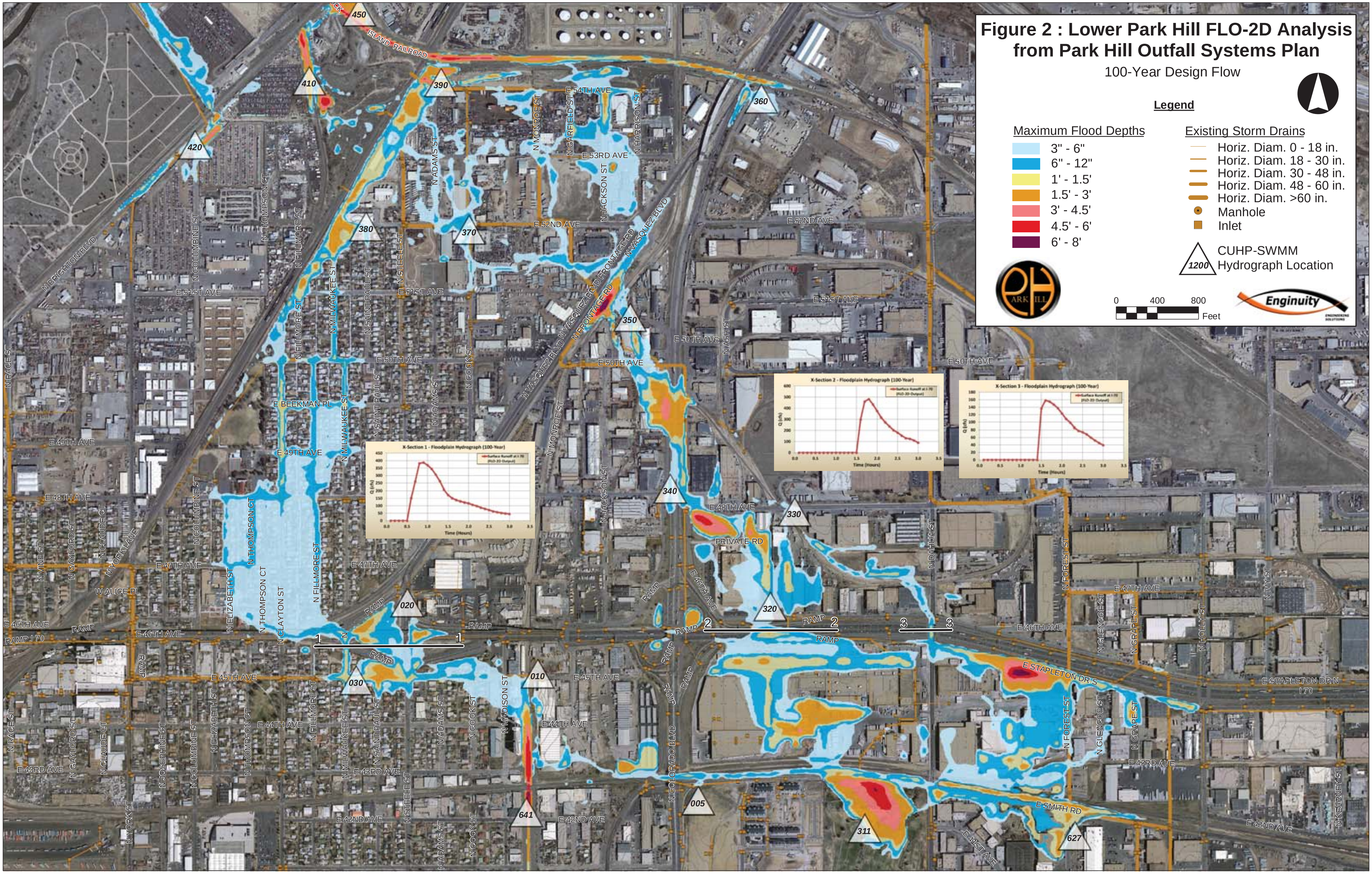


Figure 2 : Lower Park Hill FLO-2D Analysis from Park Hill Outfall Systems Plan
100-Year Design Flow
Legend
Maximum Flood Depths
3" - 6"
6" - 12"
1' - 1.5'
1.5' - 3'
3' - 4.5'
4.5' - 6'
6' - 8'
Existing Storm Drains
Horiz. Diam. 0 - 18 in.
Horiz. Diam. 18 - 30 in.
Horiz. Diam. 30 - 48 in.
Horiz. Diam. 48 - 60 in.
Horiz. Diam. >60 in.
Manhole
Inlet
1200
CUHP-SWMM Hydrograph Location
0
400
800
Feet
Enginuity
X-Section 1 - Floodplain Hydrograph (100-Year)
X-Section 2 - Floodplain Hydrograph (100-Year)
X-Section 3 - Floodplain Hydrograph (100-Year)
Time (Hours)
Q (cfs)
450
410
420
390
360
380
370
350
340
330
320
020
030
010
641
005
311
627
E 54TH AVE
E 53RD AVE
E 52ND AVE
E 51ST AVE
E 50TH AVE
E 49TH AVE
E 48TH AVE
E 47TH AVE
E 46TH AVE
E 45TH AVE
E 44TH AVE
E 43RD AVE
E 42ND AVE
E BEEKMAN PL
E STAPLETON DR S
E STAPLETON DR N
E SMITH RD
N BRIGHTON BLVD
N VASQUEZ BLVD
N FRONTAGE RD
N COLORADO BLVD
N YORK ST
N JOSEPHINE ST
N THOMPSON CT
N CLAYTON ST
N FILLMORE ST
N MILWAUKEE ST
N SAINT PAUL ST
N STEELE ST
N ADAMS ST
N COOK ST
N MADISON ST
N MONROE ST
N GARFIELD ST
N JACKSON ST
N HARRISON ST
N DAHLIA ST
N FOREST ST
N GLENCOE ST
N GRAPE ST
N HOLLY ST
N IVY ST
N KEARNEY ST
PRIVATE RD
RAMP

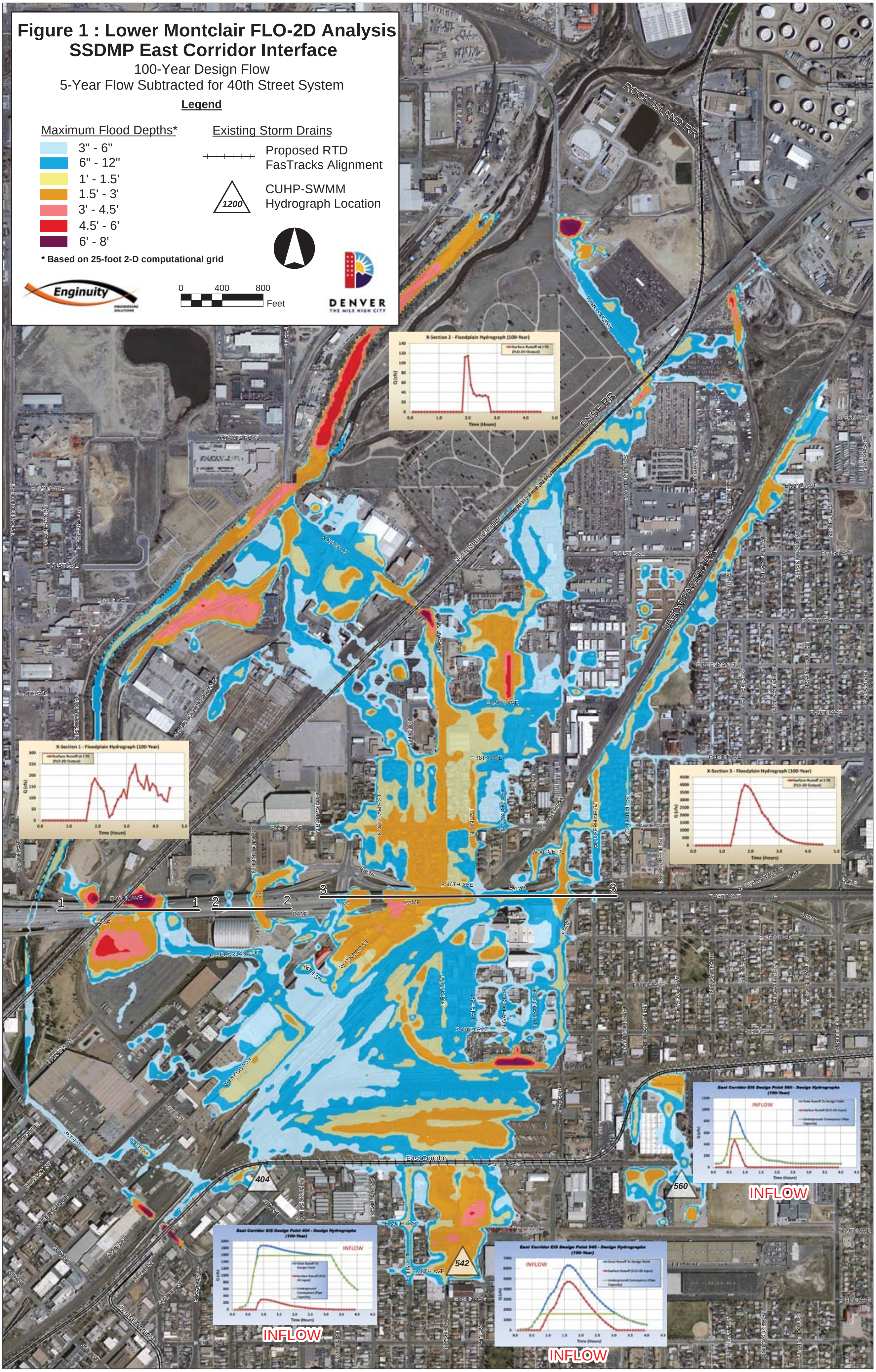


Figure 1 : Lower Montclair FLO-2D Analysis
SSDMP East Corridor Interface
100-Year Design Flow
5-Year Flow Subtracted for 40th Street System
Legend
Maximum Flood Depths*
3" - 6"
6" - 12"
1' - 1.5'
1.5' - 3'
3' - 4.5'
4.5' - 6'
6' - 8'
* Based on 25-foot 2-D computational grid
Existing Storm Drains
Proposed RTD FasTracks Alignment
CUHP-SWMM Hydrograph Location
1200
Enginuity
0 400 800
Feet
DENVER
THE MILE HIGH CITY
X-Section 1 - Floodplain Hydrograph (100-Year)
X-Section 2 - Floodplain Hydrograph (100-Year)
X-Section 3 - Floodplain Hydrograph (100-Year)
ROCK ISLAND RR
BNSF RR
UNION PACIFIC RR
East Corridor
404
542
560
INFLOW
INFLOW
INFLOW
INFLOW

Memorandum

To: I-70 PCL Drainage Multi Agency Technical Team (MATT)
- Urban Drainage and Flood Control District (UDFCD)
- Colorado Department of Transportation (CDOT)
- City and County of Denver (CCD)
- Regional Transportation District (RTD)
- Atkins
- Stantec

From: Don Jacobs P.E. – Enginuity Engineering Solutions (Enginuity)

Date: February 10, 2014

Re: I-70 PCL Montclair Drainage Basin Hydrologic Analysis

1.0 Contents of this Memorandum

This memorandum was prepared by Enginuity Engineering Solutions documenting the Multi Agency Technical Team's (MATT) investigation of the Montclair drainage basin hydrology in Denver, Colorado. A list of individual MATT participating members is located in the appendix (see meeting minutes). Organizational contents of this memorandum are listed below:

2.0 Background and Purpose

CDOT has identified the Partial Covered Lowered Alternative (PCL) as the preferred alternative for improvements to I-70 East through Denver. A portion of this alternative includes rebuilding I-70 below grade between Brighton Boulevard and Colorado Boulevard, where the existing viaduct currently stands. While lowering the highway at this location provides several enhancements to the community such as reconnecting the Elyria and Swansea neighborhoods, it also presents drainage challenges that must be addressed from a design standpoint.

The proposed lowered portion of the I-70 project crosses two major drainage basins in Denver – the Montclair and Park Hill basins. This memorandum specifically addresses the Montclair basin. Flood potential in the lower Montclair drainage basin has been documented by several previous studies, including studies by the City and County of Denver and the Regional Transportation District. These studies have defined flow rates and rough flooding limits around the I-70 area both upstream and downstream of the interstate. Currently, this flood potential does not pose a significant risk to the highway due to its elevated design on a viaduct. However, proposed lowering of alignment below grade will introduce the potential for flood waters to enter the highway if not accounted for in the project's drainage design.

To address this potential drainage issue, the MATT was formed during the fall of 2013 to collectively investigate the Montclair basin's hydrology and other inter-agency coordination issues. While the Montclair basin hydrology has been documented in several previous studies (see below for more information), all of the previous analyses were performed from a regional planning standpoint, and there was a general presumption that the previously published flow rates could potentially be overly conservative from a design standpoint.

Overall goal of this analysis: to perform a technical review of the previous Montclair basin hydrologic analysis and modify the modeling, if necessary, in order to provide C-DOT with a mutually agreed upon off-site 100-year design flow rate for the I-70 PCL project.

Previous analysis that were used as the initial basis of this project:

- 2005 CCD Storm Drainage Master Plan (SDMP)
- 2008 CCD Ferril Lake Stormwater Detention Design
- 2009 CCD Storm Drainage Master Plan
- 2010 CCD Sanitary and Storm Drainage Master Plan FasTracks Interface
- 2014 CCD Storm Drainage Master Plan (in progress, scheduled for completion in October 2014)
- 2008 RTD Draft East Corridor Drainage Master Plan
- 2011 RTD Eagle P3 Drainage Adverse Impact Analysis
- 2013 RTD North Metro FLO-2D Drainage Analysis
- 2011-2014 RTD/CCD/UDFCD 40th Avenue/High Street Outfall Design

This memorandum documents the hydrologic analysis performed by Enginuity in the Montclair basin for the I-70 PCL project's conceptual design. The analysis was a collaborative effort between MATT members with bi-weekly technical meetings held from September 2013 thru February 2014. Hydrology related meeting minutes are included in the appendix.

3.0 General Approach – Base Model Hydrology

General Hydrologic Conditions

The Montclair basin is a fully developed, urbanized watershed containing a total tributary drainage area of approximately 9.4 square miles. It encompasses drainage planning basins 4500-01, -03, and -04. The basin generally drains to the northwest and discharges to the South Platte River between Globeville Landing Park and Riverside Cemetery. Its upstream boundary is located to the southeast at the Fairmont Cemetery. Land use varies within the basin from primarily residential in the upper reaches to commercial and industrial in the lower reaches. City Park, an approximate 320 acre urban park containing the Denver Zoological Gardens, the Denver Museum of Nature & Science, and the City Park Golf Course, is located near the center of the drainage basin.

There is an extensive system of existing storm sewer pipes serving the basin including a 10' x 10' RCBC primary outfall. A second large (12' x 8' RCBC) outfall associated with the RTD Eagle P3 project in conjunction with UDFCD and CCD is currently under construction. These two outfalls combined were designed to convey the 5-year event. Surcharged flows in excess of the storm sewers' capacity are conveyed overland via the network of City streets. There is historical evidence that a drainage channel once existed in the Montclair basin, but it has since been obliterated by development during the early 20th century. Without a formal drainage channel, periodic flooding occurs throughout the basin with significant surface runoff. These areas of urban flooding are not recognized by FEMA as jurisdictional floodplains, but they pose a significant drainage design issue for the I-70 PCL project as they drain towards the highway.

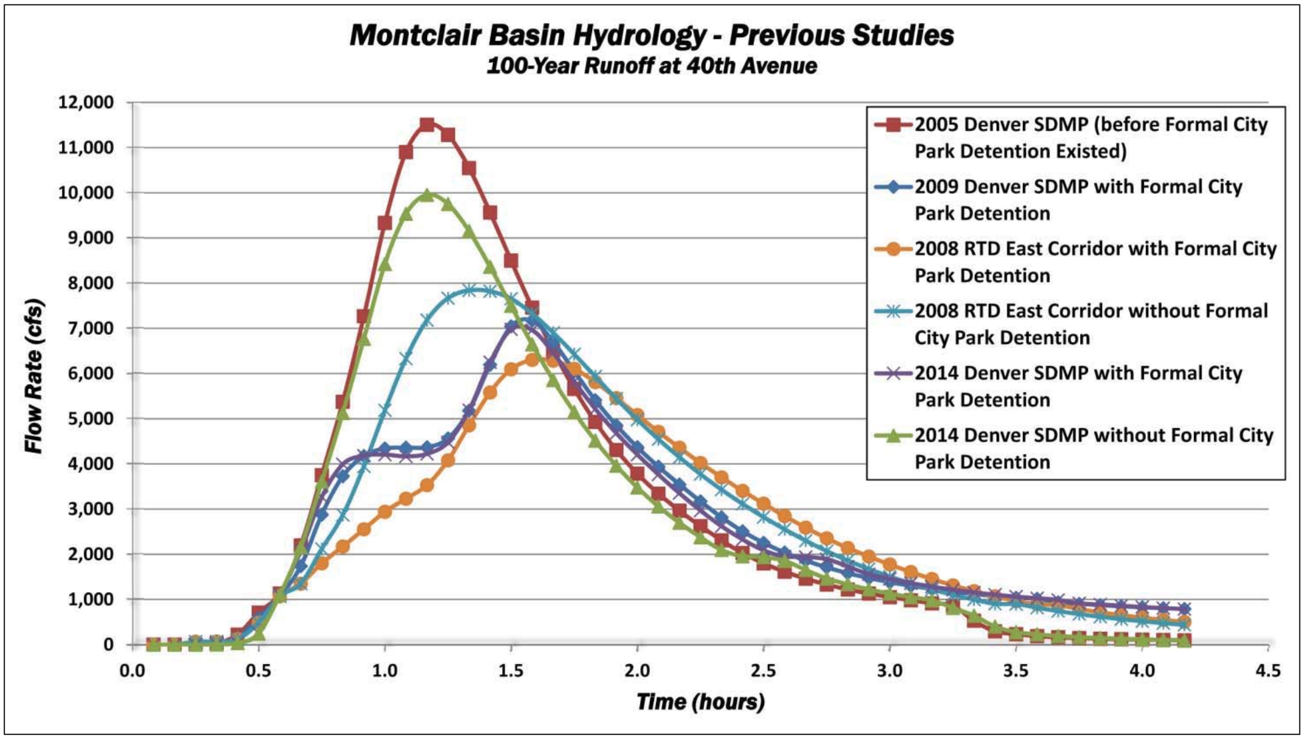
Previous Studies and Flow Rates

With numerous previous studies encompassing different portions of the Montclair drainage basin for a variety of purposes, the MATT began by investigating hydrologic results and flow rates published in the previous studies. In order to adequately compare these studies, Enginuity modified the previous CUHP/SWMM models as necessary to provide comparative results at a common location using identical assumptions. For the purpose of consistency when comparing previous studies, the following assumptions were used:

- The location for comparing flow rates produced by the Montclair basin is at 40th Avenue and represents a combined flow rate across several streets and pipes. **All flow rates published in this memorandum are at 40th Avenue.** Once water crosses 40th Avenue, it branches into several different directions and is conveyed by various underground pipes and multiple streets. These diversions downstream (north) of 40th Avenue are not analyzed in this memorandum, but will be accounted for as part of the future I-70 conceptual design, since not all of the Montclair basin's runoff reaches I-70.

- **All Flow rates throughout this study represent the total 100-year runoff from the basin (pipe flow plus surface flow).** For the sake of simplicity, underground pipe conveyances are not accounted for in the comparative flow rates and newly developed flow rates in this memorandum. These pipe conveyances will be accounted for as part of the future I-70 conceptual design.

Considering the assumptions listed above, runoff hydrographs from previous studies are depicted in the graph below:



The "City Park Detention" referenced in the graph above refers to formalized detention constructed in 2008 at Ferril Lake, which consists of approximately 124 acre-feet of detention volume and was designed for the 5-year event. While not all of the previous studies originally analyzed the basin with and without formalized detention at Ferril Lake, Enginuity added this variation to the previous models for comparative purposes and to provide the MATT with a clear understanding of the expected benefits of the existing 5-year Ferril Lake facility.

General background of the previous studies (all utilize CUHP 2000 and UDSWMM 2000):

- 2005 Denver SDMP: the first major study of the basin; utilized detailed CCD topography and GIS data; basin delineation based on pipe infrastructure; estimated % impervious values based on UDFCD land use table; delineated 57 individual sub-basins.

- 2008 RTD East Corridor: more "basic" analysis delineating 5 individual sub-basins; basin delineation based on topography; estimated % impervious values based on UDFCD land use table.

- 2009 Denver SDMP: modified 2005 model to account for City Park detention; revised % impervious calculations to be based on measured impervious values for each land use utilizing the City's GIS pervious layer; other minor modeling parameter modifications.

- 2014 Denver SDMP: modified 2009 model's routing and basin delineations to account for various surface split-flows identified using FLO-2D; routing elements account for both pipe and surface flow splits instead of pipe only; other minor modifications to account for newly constructed projects.

See the original technical documentation for each of these studies for additional information, maps, and results.

Determination of Base Hydrologic Model

The MATT reviewed results from previous modeling and decided to move forward with the 2014 Denver SDMP CUHP/UDSWMM analysis as the "Base Model" for the I-70 PCL analysis. This model was selected due to the fact that is the latest model available, incorporates both surface and pipe flow routing, and provides a significant level of additional detail over the RTD analysis. A CUHP-UDSWMM routing schematic map representing this model is located in the appendix, which includes a summary of 100-year peak flow rates for each design point. The model has been modified by Enginuity for the purposes of this study, by combining several design points into a single point at 40th Avenue to represent the total flow for the basin. The total flow is represented by Design Point "2" in the revised model.

The base model was then utilized to perform a series of sensitivity analyses accounting for potential modifications to modeling parameters that the group had identified as potentially more accurate, and also accounting for physical features observed within the basin that were not previously accounted for in the model. The results of this sensitivity analysis are discussed in the following section.

4.0 Hydrologic Modeling Sensitivity Analysis

The MATT investigated the following potential modifications to the base CUHP/UDSWMM modeling and performed a sensitivity analysis on each:

1. Accounting for **loss of surface runoff to the 36th Street** drainage basin.
2. Utilizing direct **measured impervious values** instead of land use based values.
3. Reducing the model's **discretization** by subdividing the basin into fewer sub-basins.
4. Modifying the **street routing elements** in UDSWMM to better represent flow occurring down multiple streets during the 100-year event.
5. Accounting for **inadvertent detention** that occurs within the basin.

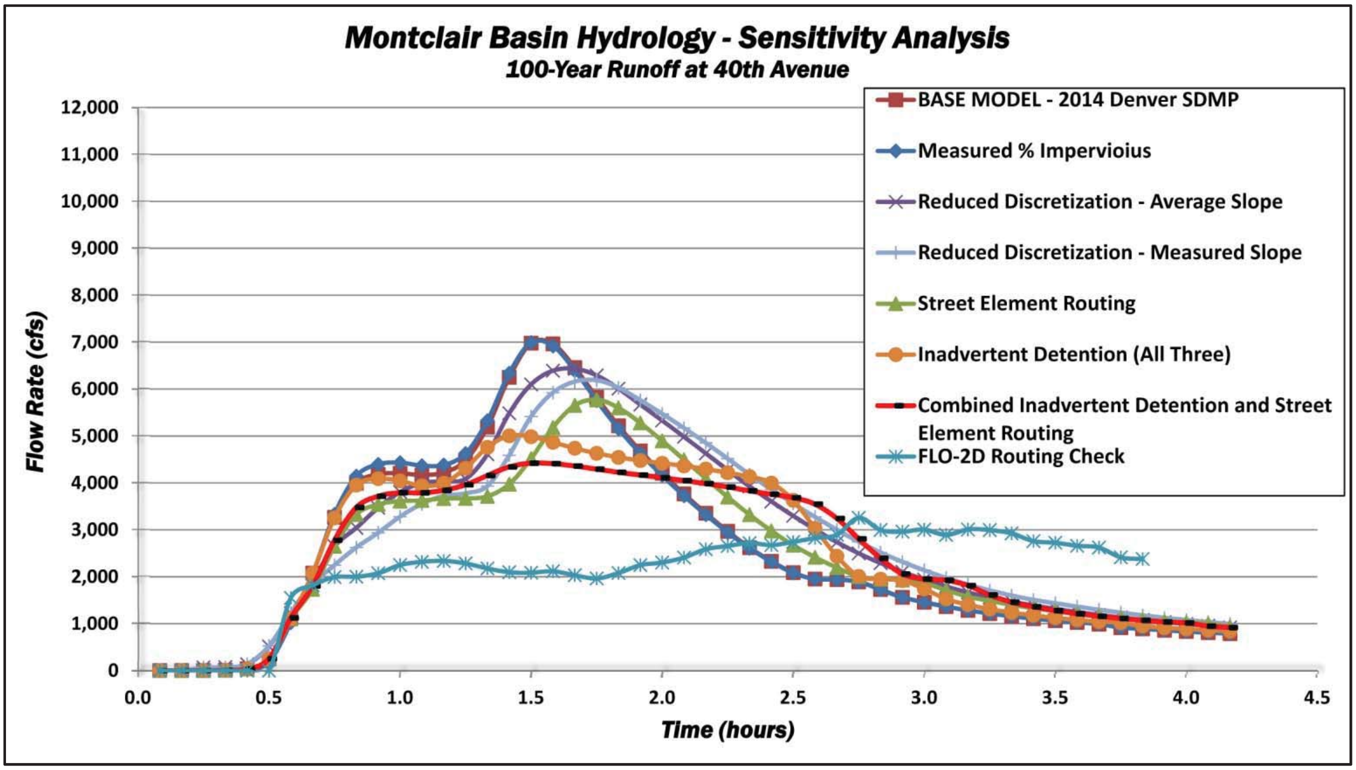
The following table and graph summarize peak runoff rates and hydrographs for the various modeling modifications investigated by the MATT. The subsequent subsections further discuss the sensitivity analysis performed for each potential modification.

Montclair Basin Hydrology – Sensitivity Analysis
100-Year Runoff at 40th Avenue

Model or Potential Modification*	Q100 (cfs)	Change from Base Model	Comment
2014 CCD Master Plan	**6979**	0%	**Base Model, CUHP 2000, UDSWMM 2000**
Loss of surface runoff to 36th Street Basin	6598	-5%	Straight subtraction of peak flow acquired from FLO-2D model
Measured % Imperviouis	6991	0.2%	1% increase in total % Impervious
Reduced Discretization - Weighted Average Slope	6432	-8%	59 sub-basins to 5 sub-basins
Reduced Discretization - Measured Basin Slope	6188	-11%	59 sub-basins to 5 sub-basins
Multiple Street X-section Routing Elements	5793	-17%	Adjusted trapazoidal bottom width and side slopes
Inadvertent Detention in City Park below Ferril Lake	5644	-19%	45.5 acre-feet assumed Inadvertent Detention
Inadvertent Detention in City Park Golf Course	5619	-19%	41.8 acre-feet assumed Inadvertent Detention
Inadvertent Detention in City Park Ball Fields	6825	-2%	18.2 acre-feet assumed Inadvertent Detention
Inadvertent Detention - all 3 combined	5005	-28%	105.5 acre-feet assumed Inadvertent Detention (total)
Check: FLO-2D Routing for Basin Below Colfax Avenue	3255	-53%	Accounts for all inadvertent detention throughout the lower basin. Includes pipe flow. Includes flow lost to 36th Street. **Low-end check only.**
<u>Modification Combinations</u>			
Multiple Street X-section Routing Elements & Inadvertent Detention (all 3 locations)	4422	-37%	Combination recommended by MATT on 12/16/2013

* All models represent total peak runoff produced by the basin, existing pipe outfalls are not considered. All models account for existing detention at City Park in Ferril Lake and also Crestmore Park.

Red = changes recommended by MATT



4.1. Loss of Water to 36th Street Basin

FLO-2D analysis performed in the 2014 Denver SDMP indicated that there is potential for some flood waters to exit the Montclair basin and enter the 36th Street basin during large storm events. The location for this potential trans-basin flow to the west would occur across Lafayette Street in the lower portion of the basin between 31st Avenue and 36th Avenue. See the Montclair-Park Hill Basin Depth map in the appendix for a depiction of this trans-basin flow location.

As part of the MATT analysis, modifications to the 2014 SDMP FLO-2D analysis were made in order to track the trans-basin flow into the 36th Street basin. The modeling results produced a trans-basin flow of 381 cfs from Montclair to 36th Street during the 100-year event. The MATT determined this amount of flow loss to be negligible and decided not to account for it in the Montclair basin hydrology.

4.2. Measured Impervious Values

As part of the MATT analysis, the impervious values for each sub-basin were directly measured utilizing CCD's impervious layer in GIS. While the exact measured values differed from the 2014 SDMP base model for individual sub-basins, the cumulative basin-wide percent impervious value only differed by 1% and produced a negligible change in runoff values. Based on this result, the MATT decided not to modify the base model's impervious values.

4.3. Reduced Discretization

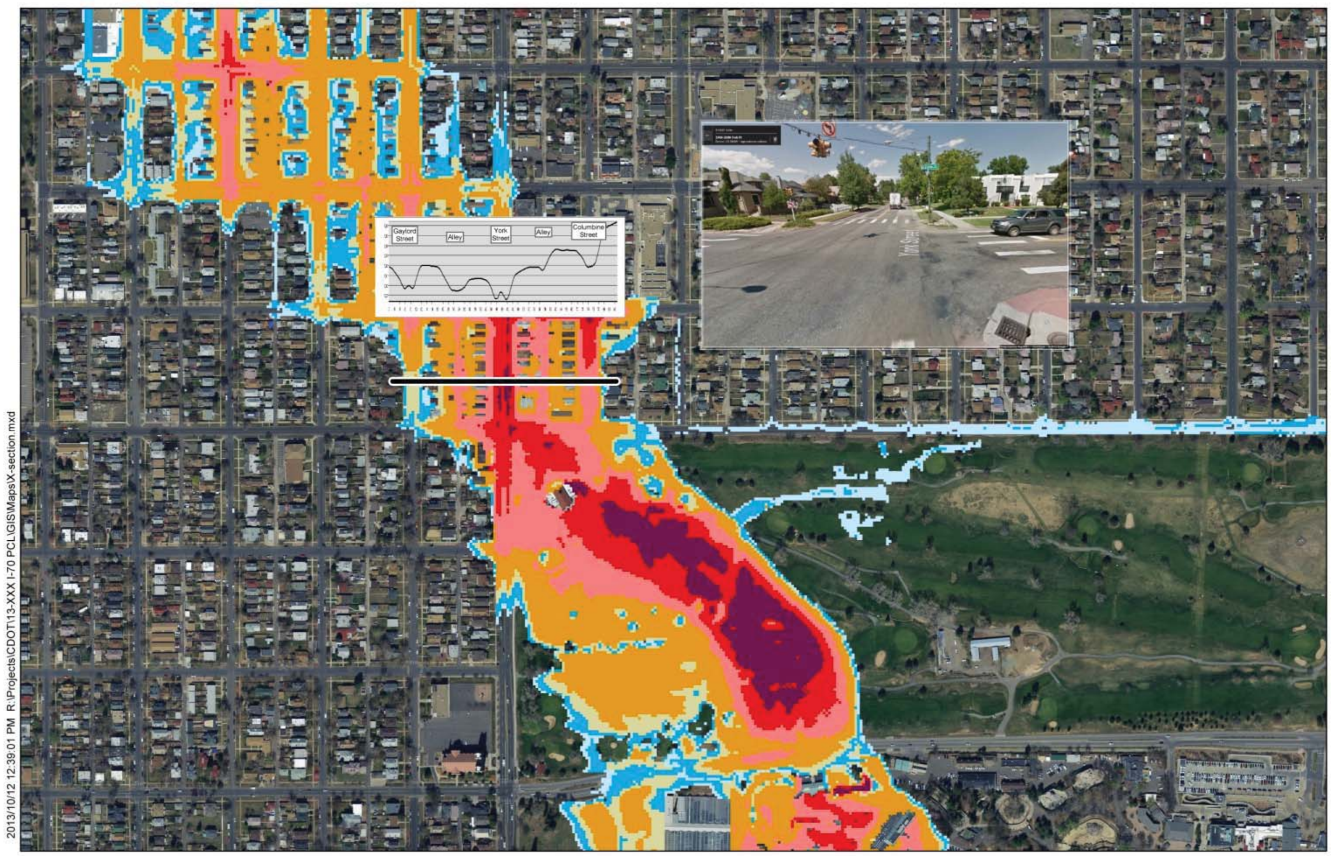
It is generally understood that the more a large basin is subdivided for CUHP/SWMM analysis (discretized), higher resulting flow rates can be expected. Often times during CUHP/SWMM model development, engineers will model a basin utilizing different levels of discretization, and compare the results in order to "calibrate" the model based on the original basis of development for CUHP itself.

The MATT checked the sensitivity of the Montclair model by reducing the discretization from 59 sub-basins in the base 2014 SDMP model to a 5 sub-basin model. The result was an 8% to 11% decrease in peak flow rates at 40th Avenue depending on the method used to calculate sub-basin slopes. The MATT determined that this difference between the two approaches was acceptable, and did not warrant modification to the base model. The MATT decided to continue with the more conservative, 59 sub-basin approach in the 2014 SDMP without further modification to account for discretization.

4.4. Multiple Street SWMM Routing Elements.

The street routing elements in the 2014 SDMP base UDSWMM model were input as recommended in the UDSWMM User's Manual. The recommended cross section is a 1-foot bottom width trapezoidal section, with 20:1 side slopes. The UDSWMM model can only accept trapezoidal shaped cross sections to represent surface flow. This standard cross section is intended to represent a street's gutter section, and can be thought of as an "inverted street crown." While this recommended cross section provides a good representation for water flowing down a single street, portions of the Montclair basin experience widespread flooding with water flowing down multiple streets, alleys, and around structures. In order to better represent the nature of this 100-year flood routing, the MATT developed several wider cross sections to be utilized in the SWMM model depending on the nature of the street flow at individual locations. The nature of the street flow was determined using FLO-2D surface modeling results from the 2014 SDMP.

A representative section located just north of 26th Avenue across the basin's primary flow path was utilized to depict the nature of street flow through the basin during the 100-year event. The following figure shows the typical nature of flow and a typical cross section within the basin, a larger version this image is available in the appendix:



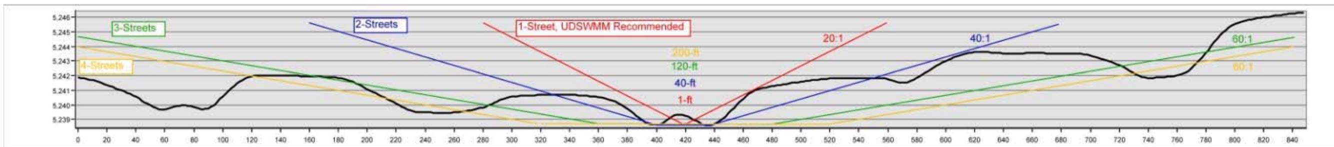
The following figure illustrates four different routing cross sections used in the MATT UDSWMM analysis representing a varying number of streets conveying the runoff. The typical ground cross section north of 26th Avenue is shown in the background in black. A larger version of this image is available in the appendix.

- Flow traveling down one street (UDSWMM User's Manual recommendation) in red. 1-foot bottom width, 20:1 side slopes.

- Flow traveling down two streets in blue. 40-foot bottom width, 40:1 side slopes.

- Flow traveling down three streets in green. 120-foot bottom width, 60:1 side slopes.

- Flow traveling down four+ streets in yellow. 200-foot bottom width, 60:1 side slopes.



When comparing these cross sections to actual ground cross sections where flow occurs down multiple streets, the MATT believes these routing element representations are conservative, with actual flooding being realistically wider, slower, and more shallow than the trapezoidal sections used in the UDSWMM model.

Several velocity checks were completed to ensure the revised trapezoidal x-section routing elements are still considered to be conservative. Results indicate that velocities calculated in SWMM for a representative trapezoidal routing element are in fact higher (more conservative) than other methods of determining flow velocities in the area. Velocity calculations performed for comparison purposes are listed below:

Velocity Check for 6000 cfs, 0.05 ft/ft longitudnal slope, 0.02 Manning's n

Manning's Velocity for Irregular Section (3-Streets):	6.8 fps
Manning's Velocity for Trapezoidal Section:	7.6 fps
EPASWMM Velocity for Irregular Section (3-Streets):	7.4 fps
EPASWMM Velocity for Trapezoidal Section:	7.8 fps (used in revised modeling)
FLO-2D Computed Velocity:	3 to 7 fps

Revision of the UDSWMM street flow routing elements resulted in a 17% decrease in peak flow rates from the base model. The MATT recommended incorporating these revisions into the I-70 hydrology to better represent 100-year flow conditions within the basin. See the UDSWMM routing map in the appendix for specific locations where the routing elements were modified to better represent street flow conditions.

4.5. Inadvertent Detention

Three areas of significant inadvertent detention were identified within the basin that could have a significant impact on peak flow rates aimed at the I-70 project. Inadvertent detention is referred to as naturally occurring detention storage that exists within low-lying and depressed areas; these areas have not been designed, constructed, or maintained for the purposes of stormwater detention. Inadvertent detention is not typically accounted for in design hydrology due to the fact it cannot be relied upon for future storage of flood waters. As a general practice, it is typically assumed that areas of inadvertent storage could be modified in the future resulting in a reduction or elimination of the storage that currently occurs. However, the three areas identified in the Montclair basin are located on CCD publically owned property, where assurances can potentially be provided to maintain the existing inadvertent detention storage volumes in perpetuity.

The MATT investigated inadvertent volumes and the impact they have on the basin's hydrology at the following locations:

1. City Park below (north of) Ferril Lake (Duck Pond area). Assume 45.5 acre-feet.

2. City Park Golf Course between 23rd and 26th Avenues. Assume 41.8 acre-feet.

3. City Park Ball Fields west of Colorado Boulevard and south of 23rd Avenue. Assume 18.2 acre-feet.

See the appendix for mapping of these three areas and assumed inadvertent detention volume calculations. These inadvertent detention volumes are considered by the MATT to be conservative, with actual 100-year inadvertent detention volumes being significantly larger than the assumed values.

The addition of these inadvertent detention volumes into the UDSWMM model results in significantly reduced flow rates at 40th Avenue. If all three areas are accounted for, a 28% reduction in 100-year peak flow rates is realized. See the table at the beginning of this section for specific results from each individual area. The MATT recommended accounting for all three inadvertent detention areas in the I-70 hydrology, provided an agreement can be made with the Denver Parks Department assuring future actions would not adversely impact the natural and formal storage currently occurring at these three locations.

4.6. FLO-2D Routing

As a "low end check" of the overall hydrologic results for the basin, runoff values from the 2014 SDMP FLO-2D model were included in the sensitivity analysis documentation. The routing of flood conveyances utilizing FLO-2D is not a methodology approved by UDFCD because it accounts for every square foot of inadvertent detention within the basin, and it is generally considered to lack enough conservatism when determining peak flow rates for design purposes. However, the FLO-2D results have been included in the sensitivity analysis tables and graphs as a simple reference point, allowing the MATT to further understand the various modeling results and help make final modeling recommendations.

5.0 Revised I-70 PCL Hydrology Results and Final MATT Recommendations

<u>Recommendations</u>

After reviewing the previous hydrologic studies performed for the Montclair drainage basin and further performing a sensitivity analysis of various modeling parameter modifications, the MATT has recommended the following modifications be made to the base 2014 SDMP CUHP/SWMM model for I-70 design purposes:

- Revise UDSWMM routing elements to more accurately represent flow occurring down multiple streets.

- Account for inadvertent detention at the following three locations: City Park Duck Pond, City Park Golf Course, and City Park Ball Fields. The inadvertent storage volumes at these locations shall only be accounted for if the proper agreements are put in place ensuring future maintenance of the flood storage volumes.

<u>Results</u>

Incorporating the MATT recommendations into the CUHP/SWMM hydrologic modeling, a revised total basin 100-year peak flow rate of **4,422 cfs** is calculated at 40th Avenue. From this value, the I-70 design team can account for existing and soon-to-be completed pipe outfalls serving the basin by subtracting their capacities from the total peak flow rate. Based on CCD's GIS data and recent construction plans, the following two main outfalls should be accounted for:

- Existing 120" BRICK @ 0.39% serving 40th Street and 40th Avenue with a calculated Manning's full flow capacity of 897 cfs.

- Currently under construction High Street Outfall (UDFCD, Denver, RTD) serving 40th Avenue and the East Corridor rail alignment with a design capacity of 906 cfs (based on construction plans dated January 2013). The latest construction plans or as-builts for this project should be referenced to verify this number.

Accounting for the two storm drain outfalls serving the Montclair basin, the 100-year design flow rate for the I-70 project at 40th Avenue (surface flow) is 2,691 cfs (4422 minus 897 minus 906). This peak flow rate can be further revised during the design process to account for the complex flood routing and split flows that occur between 40th Avenue and I-70. This flood routing analysis has already been preliminarily completed for the RTD North Metro project but should be updated using the newly revised flow rate of 2,691 cfs.

6.0 Appendix

All supporting maps, figures, tables, and hydrologic models used during the MATT analysis are provided in electronic format only. All supporting documentation can be found on the attached DVD.

The supporting documents are organized in the same general order to match the layout of this memorandum. Supporting documents include:

Figures/Maps/Tables:

- Background Montclair Mapping
  - 01. Montclair/Park Hill Basin FLO-2D Flooding Depth Analysis
  - 02. 2011-07-07 Flooding Video at 36th Avenue and High Street
  - 03. 2008 RTD East Corridor CUHP-SWMM Routing Diagram
  - 04. 2014 SDMP Base Model CUHP-SWMM Routing Diagram
- Hydrology Sensitivity Analysis
  - 01. Impervious Value Sensitivity Analysis
  - 02. Reduced Discretization Sensitivity Analysis
  - 03. Multiple Street SWMM Routing
  - 04. Inadvertent Detention
- Final Hydrologic Mapping for I-70 PCL
  - 01. **Final MATT I-70 PCL CUHP-SWMM Routing Diagram**

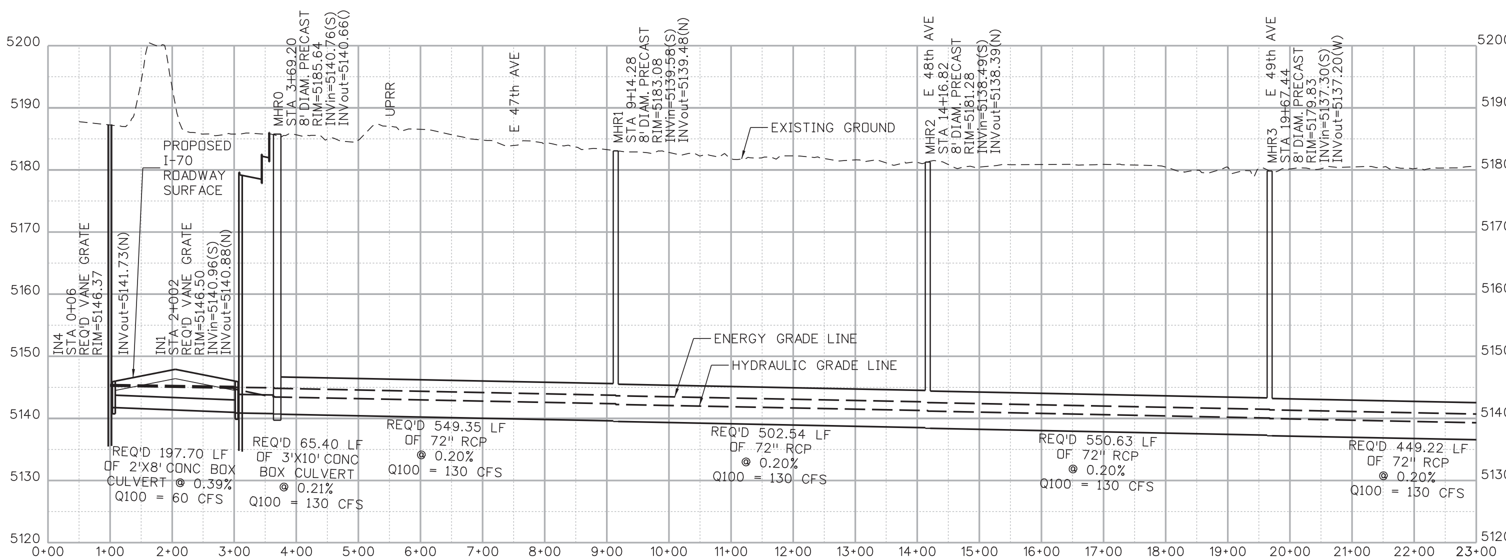
Hydrologic Models CUHP-UDSWMM:

- Previous Models Modified by Enginuity for Comparative Purposes
  - 01. 2008 RTD East Corridor (with and without Ferril Detention)
  - 02. 2014 Denver SDMP with Ferril Detention
  - 03. 2014 Denver SDMP without Ferril Detention

- Sensitivity Analysis
    - 01. Base 2014 Denver SDMP
    - 02. Measured Imperviousness
    - 03. Reduced Discretization
    - 04. Multiple Street X-section Routing
    - 05a. Inadvertent Detention City Park Duck Pond
    - 05b. Inadvertent Detention City Park Golf Course
    - 05c. Inadvertent Detention City Park Ball Fields
    - 05d. Inadvertent Detention Combined (all 3)
- Final Hydrology Revised for I-70 PCL
    - 01. Combined Inadvertent Detention and Multiple Street Routing

MATT Meeting Minutes

Attachment M – Appendix C
Onsite and offsite drainage option



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Last Modification Date: 9/10/2013	Initials: C. Das
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13599HYDR_Drainage_Onsite1_RaceSt.dgn	

I-70 EAST
ENVIRONMENTAL IMPACT STATEMENT

PRELIMINARY
SUBJECT TO REVISION

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I-70 ON-SITE DRAINAGE
OUTFALL PLAN & PROFILE

PARTIAL COVER LOWERED

BRIGHTON BLVD TO COLORADO BLVD Sheet No: 1

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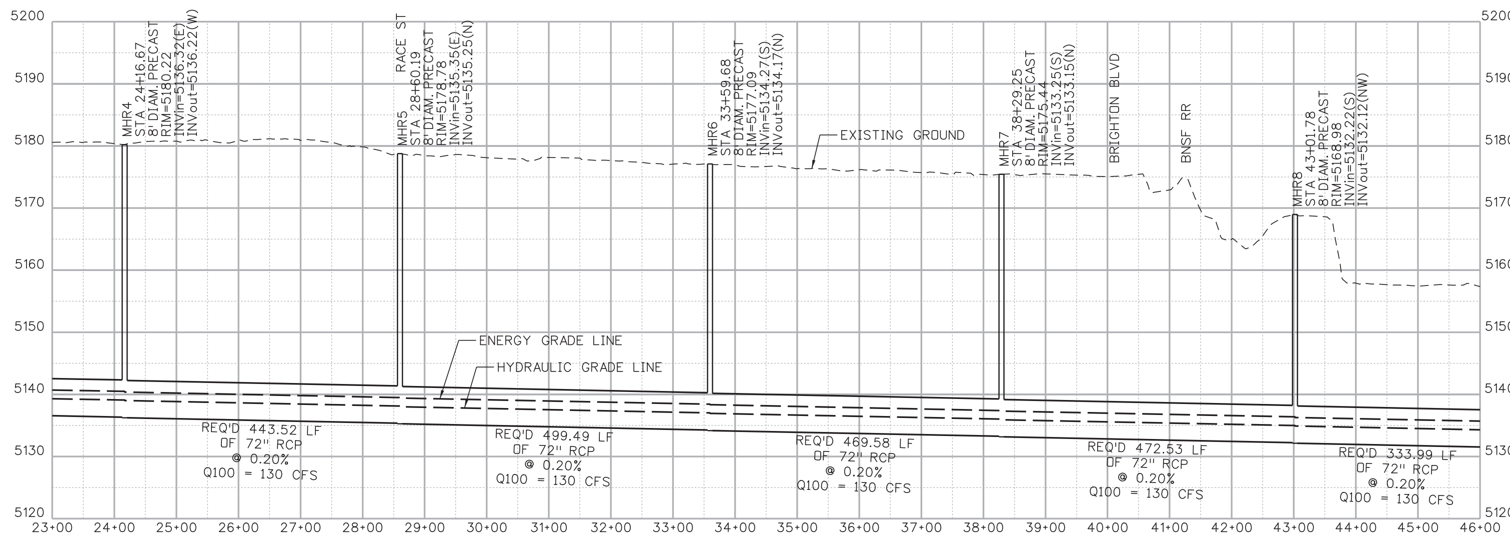

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I-70 EAST
ENVIRONMENTAL IMPACT STATEMENT

PRELIMINARY
SUBJECT TO REVISION

I-70 ON-SITE DRAINAGE
OUTFALL PLAN & PROFILE

PARTIAL COVER LOWERED

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BRIGHTON BLVD TO COLORADO BLVD Sheet No: 2

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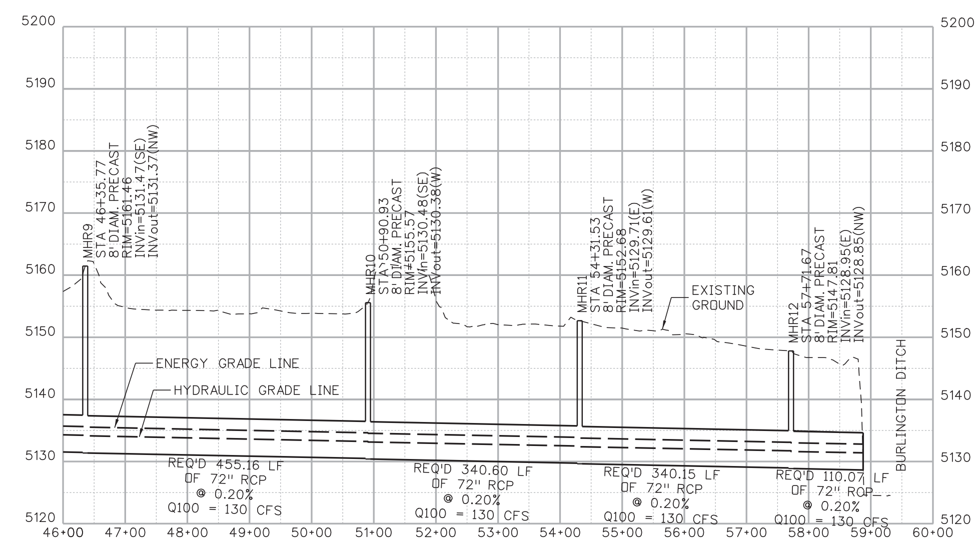

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I-70 EAST
ENVIRONMENTAL IMPACT STATEMENT

PRELIMINARY
SUBJECT TO REVISION

I-70 ON-SITE DRAINAGE OUTFALL PLAN & PROFILE

PARTIAL COVER LOWERED

BRIGHTON BLVD TO COLORADO BLVD Sheet No: 3

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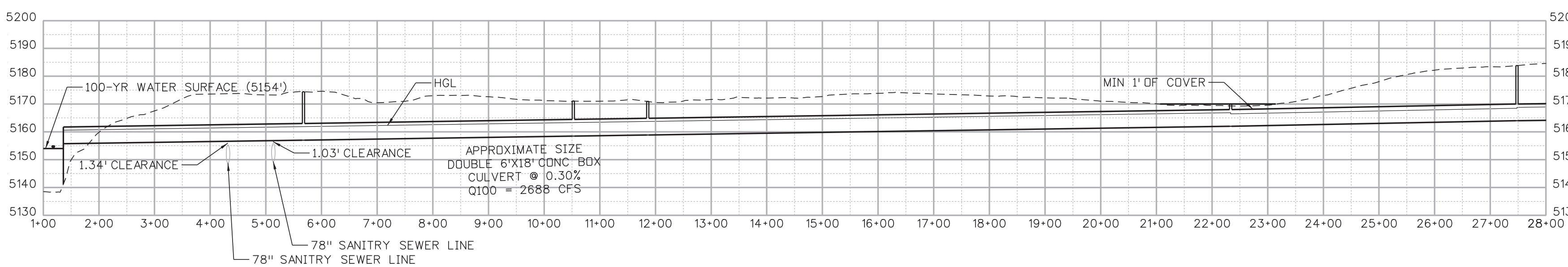

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13599HYDR_Drainage_Offsite1_Coliseum.dgn	

I-70 EAST
ENVIRONMENTAL IMPACT STATEMENT

PRELIMINARY
SUBJECT TO REVISION

I-70 LOWERED
OFF-SITE OUTFALL DRAINAGE
PLAN & PROFILE

PARTIAL COVER LOWERED

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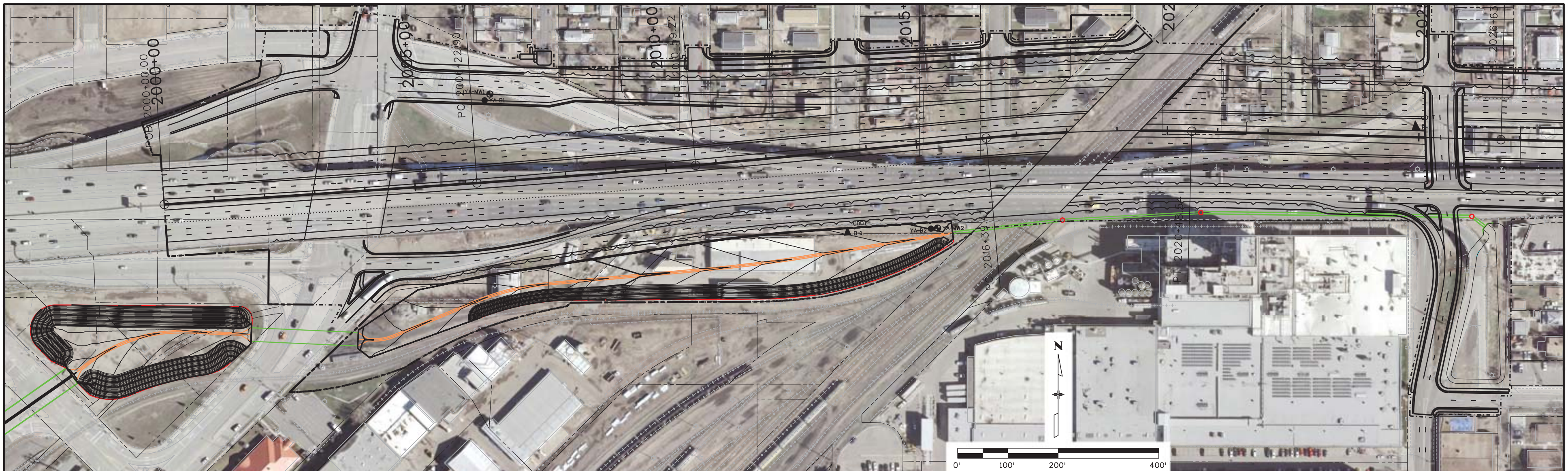
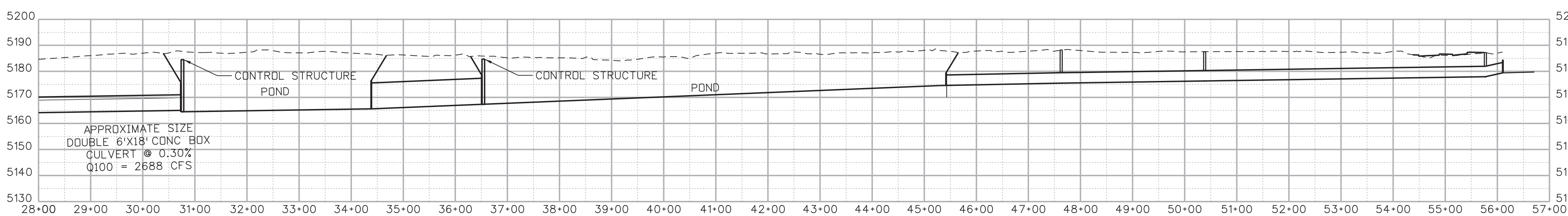
BRIGHTON BLVD TO COLORADO BLVD Sheet No: 1





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13599HYDR_Drainage_Offsite2_Coliseum.dgn	

I-70 EAST
ENVIRONMENTAL IMPACT STATEMENT

PRELIMINARY
SUBJECT TO REVISION

I-70 LOWERED
OFF-SITE OUTFALL DRAINAGE
PLAN & PROFILE

PARTIAL COVER LOWERED

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BRIGHTON BLVD TO COLORADO BLVD Sheet No: 2

22214 2:27:14 PM S:\I70Data\13599\Hydraulics\Drawings\13599HYDR_Drainage_Offsite2_Coliseum.dgn

I-70 PCL - Drainage System

FACILIRY SUMMARY TABLE

Facility ID	Pipe Size	Slope %
SD-1	6'x6' CBC	1.50
SD-2	4'x5' CBC	1.66
SD-3	5'x6' CBC	0.30
SD-4	6'x7' CBC	0.30
SD-5	4'x7' CBC	0.30
SD-6	60" RCP	0.30
SD-7	48" RCP	0.35
TRAP-8	Trap Channel (BW=6', D=2.5', SS=2:1)	1.75
SD-9	54" RCP	1.75
TRAP-10	Trap Channel (BW=6', D=2.5', SS=2:1)	1.75
SD-11	6'x6' CBC	0.77
SD-12	48" RCP	0.45
SD-13	2 6'x18' CBC	0.30
SD-14	2 6'x18' CBC	0.30

POND SUMMARY TABLE

Pond ID	Volume (ac-ft)
POND 1	5
POND 2	20
POND 3	15
POND 4	5
POND 5	5
POND 6	5
POND 7 (UPRR)	21
POND 7 (western stock show)	32